ONTARIO ASSESSMENT INSTRUMENT POOL

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OAC BIOLOGY

UNIT III

PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

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PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

Queen's Park
Toronto, Ontario

ISBN 0-7729-6270-7
CD 08710

Canadian Cataloguing in Publication Data

Main entry under title:

OAC Biology

On cover: Ontario assessment instrument pool.
"Draft".
ISBN 0-7729-6270-7

1. Biology–Study and teaching (Secondary)–Ontario.
2. Biology–Ability and testing. I. Ontario. Ministry of Education. II. Title: Ontario assessment instrument pool.

QH316.024 1989 574'.076 C89-099669-5

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS
TOPIC: Care of Environment
CURRICULAR EMPHASIS: Science, Technology and Society

INSTRUMENT CODE: B031AaER.01
GUIDELINE OBJECTIVE CODE: 31Aa
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, F.3, I.4
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: environmental damage plasmolysis vegetation.

Guideline Objective

Students should be encouraged to develop an appreciation for plants as extremely useful organisms that require care and preservation.

Item Focus

The student should be able to state concerns of two different points of view regarding a societal issue and consider ways of attempting to accommodate both viewpoints.

Item

In Canada, icy roads in winter are a major safety concern. Often, sand or salt is used to lessen the danger to motorists. However, salt can cause considerable damage to vegetation located near roads and highways. Environmentalists express concern over the increased damage to vegetation.

A. State the major aspects of the problem which must be addressed by decision-makers.

B. Suggest four possible ways to minimize the effects of salt on vegetation near roadways.

C. In metropolitan areas, what are the consequences for aquatic ecosystems of salt in the run-off?

Response/Marking Scheme

A. Two aspects of the problem are:

1. how to reduce the dangerous conditions which exists on icy roads, and,

2. how to minimize the damage to vegetation in dealing with 1). 2

B. If salt and sand are the only ways of dealing with the icy-road conditions at this time, then ways must be taken to limit the spreading of the substances from the roads to the nearby vegetation. Possible ways might be:

(Accept any 4 valid points)

- surround the sand and salt particles with a material which is sticky or dense and hence will not be carried by the wind, but which is non-toxic and biodegradable, 2
- use dispersal methods which drop the material directly on the road as opposed to spreading the material, 2
- develop strains of plants that are not as susceptible to damage caused by salt, 2
- provide some sort of physical barrier to minimize the spreading of salt to nearby vegetation. 2

C. Salt in the water disrupts the osmotic concentrations of rivers and flood plains. This gives salt-tolerant species a competitive advantage over local species. 2

Possible: 12

Maximum: 10

Teacher Notes

Be prepared to accept valid points for your particular region. In the North, salt is not effective in melting ice at the lower temperatures. The salt also attracts animals to the roadways, where they become a hazard to drivers.

Snow throwers may pile snow and salt onto adjacent vegetation.

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031AaER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Aa, Pt 1, 3.1 (5,11)
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	INSTRUMENT TYPE: ER
	KLOPFER: A.1, A.3, F.3, H.1, H.2, H.3, I.4
TOPIC: Science and Society	
CURRICULAR EMPHASIS: Science, Technology and Society	DIFFICULTY LEVEL: H
	TIME ALLOCATION:

KEYWORDS: environment conservation areas decision making

Guideline Objective

Students should be able to apply science concepts, processes and values in investigating everyday problems and in making decisions in which technology and social issues are involved.

Item Focus

Students will demonstrate how science can inform a decision, but is not necessarily the most influential factor in making a societal decision.

Item

In recent years, parks and conservational areas have been set aside near large metropolitan areas for use as recreational areas for people. In some cases, these areas are relatively costly to maintain and also prevent expensive land from being commercially developed. Yet there is a feeling in the general population that these areas are important and worth the expense. Assume that you are a member of a group of decision-makers that must decide if a section of land is to be designated as a recreational park or as an area for industrial development.

A. Discuss three major considerations which might enter into the decision.

B. In what ways might scientific knowledge be used in the decision-making?

C. Do you think the scientific information is going to have a significant influence on the decision? Why?

Response/Marking Scheme

A. Accept any three of:

(i) the amount of available recreational facilities already in existence,

(ii) the crime-rate and the need for more recreational opportunities for people in the area,

(iii) the availability of funds to finance and maintain a recreational area,

(iv) the jobless rate in the area, and the opportunity to create jobs for these people in the recreational area,

(v) the availability of transportation,

(vi) uniqueness of the resource,

(vii) involvement of local residents — any 3: 3

B. Scientific knowledge may contribute to the decision by providing information about the suitability of the land for a recreational area in terms

(i) of the drainage conditions,

(ii) the type of soil present (good or poor soil for growing grass, trees, etc.),

(iii) the degree of erosion which may take place, etc. — 3

C. The scientific information provided to the group may not have a significant impact, — 1

unless the land is said to be unsuitable. — 1

Even this may not have too great an effect because if other sociological arguments are in favour of the recreational project (or against it), sufficient monies will probably be found to make the land more suitable. The decision may be made in this case based more on perceived sociological need than on scientific considerations. — 1

Possible: 9

Maximum: 6

Teacher Notes

Note: Adapt the question to suit local conditions or issues.

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031AaSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Aa
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	KLOPFER: A.1, A.3, F.3, H.1, I.4, I.5
TOPIC: Science and Society	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Science, Technology and Society	TIME ALLOCATION:

KEYWORDS: research funding decision making issues

Guideline Objective

Students will be given opportunities to understand the relationships between science and society in such areas as economics.

Item Focus

The student will state and defend criteria for making a decision within the body of science, and state that some of the considerations are outside the domain of science.

Item

Suppose that you are in charge of allocating funds for science research, and there is only $ 50 000 left in the research budget. Two research projects need funds. One research programme deals with the testing of new ideas and chemicals to combat the spread of Dutch elm disease, a fungal infection that kills elm trees. The other research program concerns the testing of chemicals that show promise in the prevention of certain types of human cancer.

State three important criteria you would use in making your choice.

Response/Marking Scheme

Accept any three of:

(i) consideration of the research record of the people in the two programmes,

(ii) quality of the arguments used by the people in the two programmes in their attempt to convince one of the merit of their programmes,

(iii) solicit opinions of knowledgable people in the two areas as to the soundness of the research programmes,

(iv) assessment of the chances of success,

(v) consideration of new or old lines of research.

Possible: 3

Maximum: 3

Teacher Notes

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DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031AaSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Aa
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	KLOPFER: A.1, A.3, F.3, H.1, I.4, I.5
TOPIC: Science and Society	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Science, Technology and Society	TIME ALLOCATION:

KEYWORDS: research funding decision making issues

Guideline Objective

Students will be given opportunities to understand the relationships between science and society in such areas as economics.

Item Focus

The student will state and defend criteria for making a decision within the body of science, and state that some of the considerations are outside the domain of science.

Item

Suppose that you are in charge of allocating funds for science research, and there is only \$ 50 000 left in the research budget. Two research projects wish need funds. One research programme deals with the testing of new ideas and chemicals to combat the spread of Dutch elm disease, a fungal infection which kills elm trees. The other research program concerns the testing of chemicals which show promise in the prevention of certain types of human cancer.

State two ways in which you would ensure that all the research money does not go to one area of science (such as the medical sciences).

Response/Marking Scheme

Accept any two of:

(i) Establish a group consisting of members from a variety of branches of sciences to decide on the allocation of research funds,

(ii) designate a level of funding that must go to each branch of scientific research,

(iii) set a maximum percentage of all science research funds that can be given to any one branch of science.

Possible: 2

Maximum: 2

Teacher Notes

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DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SaLS.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sa 32a
UNIT NUMBER: 03	INSTRUMENT TYPE: LS
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.7, B.1, B.2, B.3
TOPIC: Leaf Structure	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: chloroplast lab algae

Guideline Objective

Students will have the opportunity to develop skill in preparing and examining wet-mount slides of algae and leaf tissue to identify the location, shape, and size of chloroplasts.

Item Focus

The student will demonstrate skill in preparing and examining wet-mount slides of algae and leaf tissue to identify the location, shape, and size of chloroplasts.

Item

A. Make a wet-mount slide of a few strands of the filamentous alga provided. Focus and select a typical filament. Make a careful drawing of one cell, sketching its neighbouring cells. Write a description of the location, shape, and number of chloroplasts.

B. Make a wet-mount of a young leaf from near the tip of a young shoot of *Elodea*, the Canada waterweed. Focus, and select an area where the leaf is thinnest. Make a careful drawing of one cell, sketching its neighbouring cells. Write a description of the size, shape, and number of chloroplasts in the cell.

Response/Marking Scheme

A. Drawing of alga cell 3

Scale indicated

Description (one of *Spirogyra* or *Zygnema*) Maximum: 5

Spirogyra chloroplasts are conspicuous, green ribbon-shaped, wound spirally just inside the cylindrical walls from one end of the cell to the other: quite long. They are thin and narrow, with scalloped edges. They have prominent circular spots arranged at regular intervals. Their number: from 1 to 12 (depending on the species).

or

Zygnema chloroplasts are conspicuous, green, star-shaped suspended in the cytoplasm in each half of the cylindrical cell; larger than the cell nucleus. The radiating arms of each star reach out into the cytoplasm lining the cell wall. There are 2 chloroplasts.

B. Drawing of *Elodea* cell 3

Scale indicated

Description of *Elodea* Maximum: 5

Chloroplasts of *Elodea* are conspicious, green, small, oval or spherical in shape, suspended in the cytoplasm just inside the cell walls. There may be as many as 100 per cell.

Total: 16

Teacher Notes

1. This lab requires students to make wet-mount slides of filamentous alga, such as *Spirogyra* or *Zygnema*, and an *Elodea* leaf, and observe the relative shapes, location, and number of chloroplasts.

2. These activities could form two stations of a practical lab test, each requiring ten minutes.

Materials: (for each two students)

	compound microscope
2	microscope slides
2	coverslips
	live filamentous alga, such as *Spirogyra* or *Zygnema*
	live *Elodea*

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DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SbLE.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sb
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.7, B.1, B.2, B.3, B.5, G.1,G.2
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: stomata photosynthesis lab

Guideline Objective

Students will have the opportunity to develop skill in examining prepared slides or electron micrographs of leaf sections to study stomata, the structure of chloroplasts and the location and structure of various leaf tissues.

Item Focus

The student should be able to estimate the number and size of stomata in the upper and lower surfaces of a leaf and discuss the significance of their observations with respect to the advantages and/or disadvantages to the plant.

Item

A. Prepare and examine a nail polish peel from the upper and lower surface of a privet leaf.

B. Draw a labelled diagram of a stoma as seen on the peel at 45X magnification and estimate the size of the stoma (length and width) at this magnification.

C. Estimate the total number of stomata on the upper and lower surface of the leaf.

D. State the significance of the stomata with respect to the general physiology of the plant and/or disadvantages to the plant of their distribution.

<u>Calibration of the Microscope:</u>

Given: $\pi = 3.1416$
area of a circle = πr^2 (where r is the radius)
measure diameter of the 10X objective field of view
(= say 1.4 mm)
unit of microscopic measurement is a μm
where

$$1\mu m = \frac{1}{1000} mm$$

to calculate diameter of 45X objective field of view:

Ratio of Magnifying Powers

$$\frac{\text{magnifying power of 45X objective}}{\text{magnifying power of 10X objective}} = \frac{45}{10} = 4.5$$

therefore, diameter of 45X field of view

$$= \frac{\text{diameter of 10X field of view}}{4.5}$$

<u>Materials Available:</u>
- smooth leaves
- microscope with 10X and 45X objectives
- microscope slide
- 2 cover slips
- eye dropper
- small beaker of water
- nail polish and brush
- mounted needle
- forceps
- squared (or graph) paper

Method:

1. Paint a thin single coat of nail polish over a small area (about 1cm) of both the upper and lower surfaces of the leaf. **Caution: The solvent is toxic, highly volatile and flammable. Do this step under a fume hood.**

2. Allow to dry thoroughly.

3. Use a dissecting needle and forceps to peel the nail varnish off the leaf.

4. Mount the peels in two drops of water on a microscope slide.

5. Place cover slips over each drop of water and examine under 10X and 45X objectives.

6. Ask your teacher to evaluate your 'peels'.

7. Complete parts B, C, and D of the item.

8. Submit all your calculations, including your rough work.

Response/Marking Scheme

A. <u>Evaluation of peels:</u> - clarity

- wholeness
- well mounted 3

B. <u>Labelled diagram of stoma:</u> - diagram

- guard cells
- pore
- epidermal cells 4

Estimate the size of the stoma at 45X magnification

Given: Diameter of high power field of view (45X) (1400 μm)

$$= \frac{\text{diameter of low power field of view (10X)}}{4.5}$$

$$= \frac{1400}{4.5}\mu\text{m}$$

$$= 311\mu\text{m}$$ 1

estimated length of stoma 1

estimated width of stoma 1

C. Area of leaf viewed under 45X objective field of view

$= \pi r^2$

= 3.1416 x 0.156mm x 0.156 mm (diameter = 0.311 mm)
= <u>0.076 mm</u> (r= 0.156) 1

Average number of stomata per 45X objective field of view on upper surface = 1

on lower surface = 1

Adequate number of samples (five?) to obtain average, on both surfaces. 1

Estimate total area of upper surface (or lower surface) of leaf. Trace around the leaf on the squared paper and calculate total area of squares covered. 2

Estimate total number of stoma on lower surface

$$= \frac{\text{area of lower surface (mm or cm)}}{\text{area of 45X field of view (mm or cm)}} \times \begin{array}{c}\text{Av.\# of stomata in}\\ \text{45X field of view}\end{array}$$ 2

- same for upper surface (probably zero) 1

D. Carbon dioxide required for photosynthesis diffuses from the air into the leaf through the pores of the stomata. 1

Water vapour diffusing from the leaf into the air through the pores of the stomata maintains the transportation pull in the xylem vessels, carrying the water required for photosynthesis from the roots to the leaves. 2

Advantage of having stomata on the lower surface is to restrict the loss of water vapour by transpiration, reducing ther possibility of dehydration. 1

Disadvantage is that the carbon dioxide enters the leaf through the surface further away from the photosynthesizing palisade layer of cells. 1

Possible: 24

Maximum: 20

Teacher Notes

1. Place small fresh sprigs of a smooth-leaved plant, such as privet, in beakers of water at each student's location.

2. Use a deeply coloured transparent nail polish.

3. The amount of detail given to the student is left to the teacher's discretion.
   eg. -value of π, value of a μm?
   -formula for area of a circle
   -details of how to calculate the area of a leaf
   -seen under the 45X objective lens

4. Evaluate the student's nail polish peels.

Materials for the laboratory: (per student)

-freshly picked smooth leaves, e.g. privet.
-microscope with 10X and 45X objectives
-microscope slide
-2 cover slips
-eye dropper
-small beaker (for water)
-nail polish and brush
-mounted needle
-squared (or graph) paper
-forceps

Safety Precautions:

Nail polish solvent is toxic, volatile and highly flammable. Use fume hoods,and caution students to avoid inhaling the vapour. Avoid open flames in the laboratory during this exercise.

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DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SbSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sb
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Leaf Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: scanning electron micrograph

Guideline Objective

Students will have the opportunity to develop skill in examining prepared slides or electron micrographs of leaf sections to study stomata, the structure of chloroplasts and the location and structure of various leaf tissues.

Item Focus

The student should be able to identify leaf structures shown in an electron micrograph.

Item

PORTION OF A FLOWERING PLANT

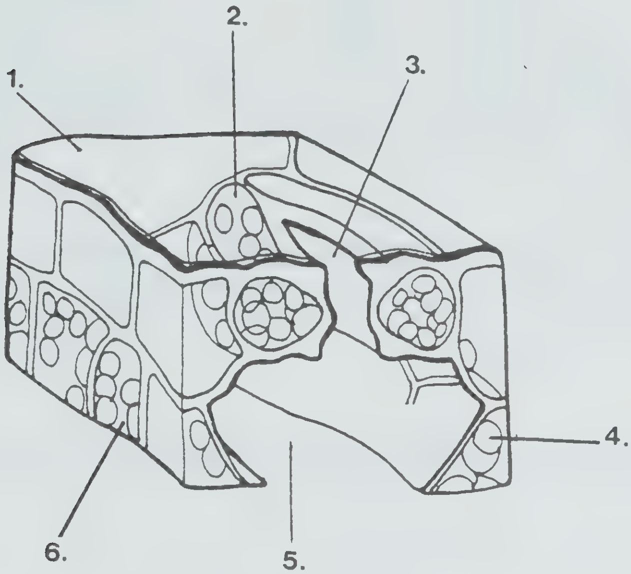


Figure 3S.1 is a drawn from a scanning electron micrograph of a portion of a flowering plant, magnified 1470 times. Numbers 1, 2, and 6 refer to cell types. The rest are either spaces or organelles. Identify the numbered parts.

1. ______________________

2. ______________________

3. ______________________

4. ______________________

5. ______________________

6. ______________________

Response/Marking Scheme

1. (lower) epidermal cell	1
2. guard cell	1
3. stoma	1
4. chloroplast	1
5. air space (intercellular space)	1
6. spongy mesophyll cell (chlorenchyma cell)	1
Possible:	6
Maximum:	6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SbSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sb
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11
TOPIC: Photosynthesis	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chloroplasts grana

Guideline Objective

Students will have the opportunity to develop skill in examining prepared slides or electron micrographs of leaf sections to study stomata, the structure of chloroplasts and the location and structure of various leaf tissues.

Item Focus

The student should be able to examine electron micrographs of leaf sections to study stomata.

Item

Refer to Figure 3S.2.

Supply a title for the Figure, and identify the structures indicated by the letters.

Response/Marking Scheme

Title:	Electron micrograph of a Pair of Guard Cells and associated tissue, or A Stoma, and Surrounding Epidermis of a Leaf	2
Labels:	A. epidermal cell B. chloroplast C. vacuole D. stoma E. nucleus	5
	Possible:	7
	Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SbSA.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sb
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11
TOPIC: Chloroplast Structure	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chloroplasts grana

Guideline Objective

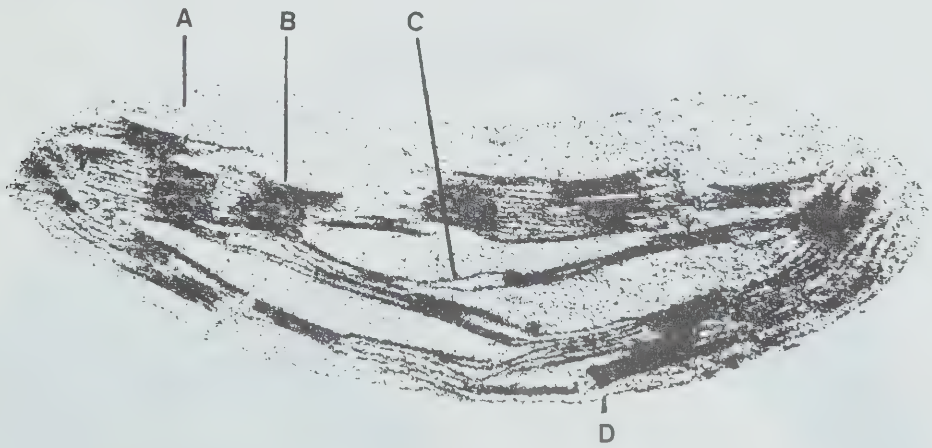
Students will have the opportunity to develop skill in examining prepared slides or electron micrographs of leaf sections to study stomata, the structure of chloroplasts and the location and structure of various leaf tissues.

Item Focus

The student should be able to examine electron micrographs of leaf sections to identify the structure of chloroplasts.

Item

Refer to Figure 3S.3.



Supply a title for the Figure, and identify the structures indicated by the letters.

Response/Marking Scheme

Title: Electron Micrograph of a Chloroplast — 2

Labels: A. stroma
B. grana
C. stroma lamella or inter grana lamella
D. plastid membrane — 4

Possible: 6

Maximum: 6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SbSA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sb
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11
TOPIC: Photosynthesis	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chloroplasts grana

Guideline Objective

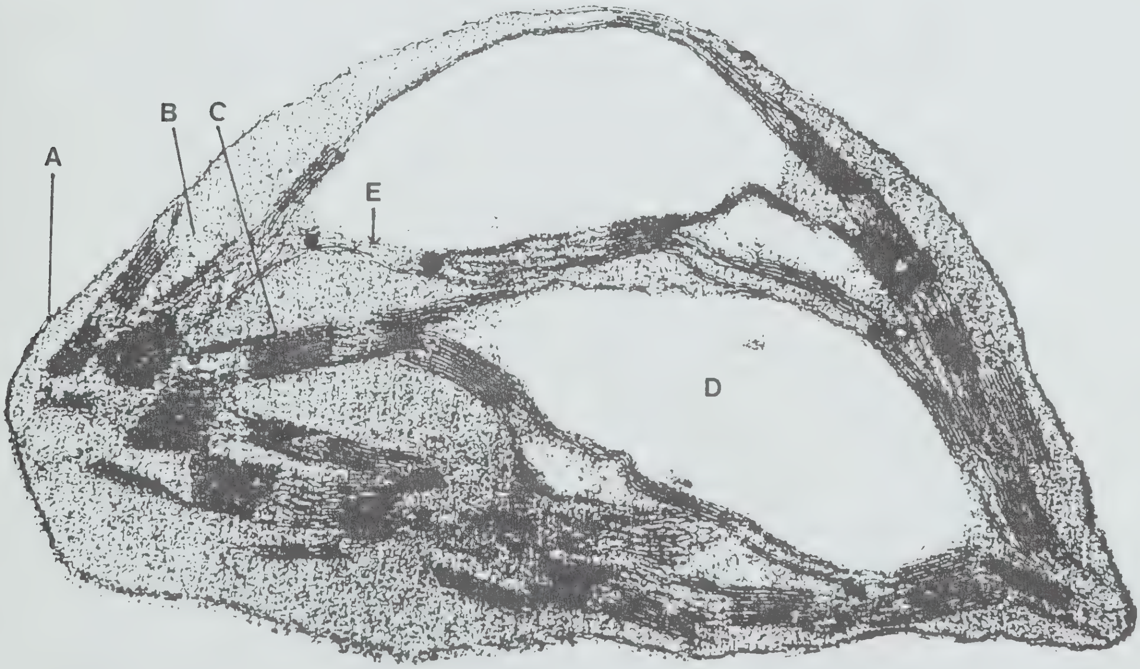
Students will have the opportunity to develop skill in examining prepared slides or electron micrographs of leaf sections to study stomata, the structure of chloroplasts and the location and structure of various leaf tissues.

Item Focus

The student should be able to examine electron micrographs of leaf sections to identify the structure of chloroplasts.

Item

Refer to Figure 3S.20.



Supply a title for the Figure, and identify the structures indicated by the letters.

Response/Marking Scheme

Title: Electron Micrograph of a Chloroplast 2

Labels: A. plastid membrane

B. stroma

C. grana

D. starch granule or lipid droplet

E. stroma lamella 5

Possible: 7

Maximum: 7

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLE.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.8, B.1, B.3, B.4, D.1, D.2, D.3, D.5, D.6
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light intensity lab

Guideline Objective

Students will have the opportunity to develop skill in designing and performing experiments to study the effects on the rate of photosynthesis and performing experiments to study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature, and quality of light.

Item Focus

The students should be able to perform an experiment to show the effects of the quality of light on the rate of photosynthesis.

Item

This laboratory activity is designed to let you determine the rate of photosynthesis of a plant by measuring the rate at which oxygen is released. This is most easily done with a plant that lives under water: *Elodea*. Since oxygen is not very soluble in water, it is set free from the cut ends of the stems as bubbles of gas. The increase in pressure due to the released gas will drive a drop of coloured liquid along the capillary tube. The rate at which the drop moves is used as an estimate of the rate of photosynthesis.

Problem: How does the quality (colour) of light affect the rate of photosynthesis?

Procedure:

1. Set up the apparatus as shown in Figure 3.1. Use the syringe to introduce a drop of water with vegetable colouring into the capillary tubes. Fill the test-tubes to within 5 mm of the stopper with the sodium hydrogen carbonate solution.

2. Cut the stems of 2 or 3 tips of healthy *Elodea* sprigs, about 8 cm long. Place the *Elodea* stems in one test tube, with their cut ends at the top.

3. Place the 2-holed stoppers into the test tubes. Use the syringes in the short glass tubes to adjust the positions of the drops of coloured water near the elbows of the capillary tubes.

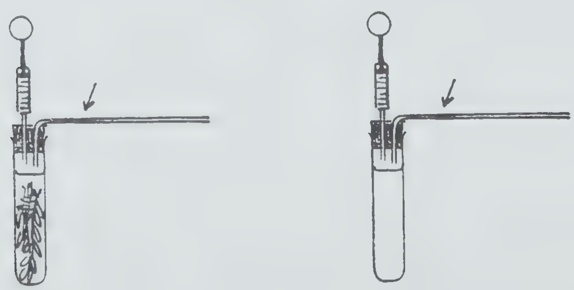
4. Place the light source 20 cm away from the tubes, and measure the rate of photosynthesis. Readjust the coloured drops and repeat the measurements.

5. Pour out the liquid in each test tube, and refill them with the fresh carbonate solution. Place a coloured filter over the light source and repeat the measurements.

6. Repeat the experiment with different coloured filters.

<u>Observation Table:</u>

Light Source	Rate of Movement of Coloured Drop		
	with *Elodea*	without *Elodea*	Difference
white light			
red filter			
green filter			



Questions:

1. What relationship can you establish from your data between the rate of photosynthesis and the quality or colour of the light source?

2. What would you have to do to convert your relative measurements into absolute quantities of oxygen produced under different wave lengths?

3. Name one other factor affecting the rate of photosynthesis you could investigate with some modification of the set up you used in this experiment. Describe the modification you would use.

Response/Marking Scheme

Experimental Technique	5
Results	4
<u>Answers to Questions</u>	
1. The colour or wave length of light affects the	1
rate of photosynthesis; white light produces the fastest rate ;	1
red light stimlates faster rates than other colours.	1
2. Measure the volume of the bore of the capillary tube	1
by displacing gas through the system	1
from the pipette.	1
3. Answers will vary. Some acceptable responses: Intensity of the light source	1
Use different sources, or the same source at different distances.	1
or	
Concentration of carbonate solution (carbon dioxide)	(1)
Use solutions that are more (or less) concentrated in sodium hydrogen carbonate, say 5% or 0.5%.	(1)
or	
Temperature	(1)
Surround test tube with a water bath and control temperatures through a range such as $5^{\circ} - 31^{\circ}C$.	(1)
Possible:	17
Maximum:	15

Teacher Notes

1. In this activity, the rate of photosynthesis is indicated by the pressure of the oxygen released by a sprig of water plant. The pressure is measured using a manometer. A control tube is set up without a plant.

2. Different lab teams could be assigned a variety of conditions to try: see the next three lab instruments.

3. Advance preparation: let tap water stand for 2 days for the chlorine to escape. Prepare the hydrogen carbonate solution.

4. The laboratory should require 30 min.

   Materials: (per team of 2 students)

1	beaker, 600 mL
2	test tubes, 20 x 150 mm
2	syringes, 1 mL
2	stoppers, 2 - holed to fit test tubes (#6)
2	adjustable clamps
2	short glass tubes with rubber sleeves
2	capillary tubes, bent at 90°
1	metre stick
1	light source (100 W bulb in an upright lamp, or fluorescent growth lamps)
	Elodea or other suitable water plant
	solution of vegetable colouring
	solution of sodium hydrogen carbonate, 1%

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLE.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.8, B.1, B.3, B.4, D.1, D.2, D.3, D.5, D.6
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: carbon dioxide concentration lab

Guideline Objective

Students will have the opportunity to develop skill in designing and performing experiments to study the effects on the rate of photosynthesis and performing experiments to study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature, and quality of light.

Item Focus

The students should be able to perform an experiment to show the effects of the concentration of carbon dioxide on the rate of photosynthesis.

Item

This laboratory activity is designed to let you determine the rate of photosynthesis of a plant by measuring the rate at which oxygen is released. This is most easily done with a plant that lives under water: *Elodea.* Since oxygen is not very soluble in water, it is set free from the cut ends of the stems as bubbles of gas. The increase in pressure due to the released gas will drive a drop of coloured liquid along the capillary tube. The rate at which the drop moves is used as an estimate of the rate of photosynthesis. Since it is difficult to control the concentration of carbon dioxide dissolved in water, you will use known concentrations of sodium hydrogen carbonate solution as the source of carbon for photosynthesis.

Problem: How does the concentration of carbonate affect the rate of photosynthesis of a water plant?
Procedure:

1. Set up the apparatus as shown in Figure 3.1. Use the syringe to introduce a drop of water with vegetable colouring into the capillary tubes. Fill the test-tubes to within 5 mm of the stopper with the sodium hydrogen carbonate solution.

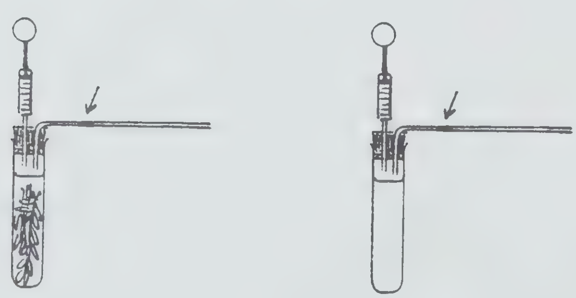
2. Cut the stems of 2 or 3 tips of healthy *Elodea* sprigs, about 8 cm long. Place the *Elodea* Place the stems into one test tube, with their cut ends at the top.

3. Place the 2-holed stoppers into the test tubes. Use the syringes in the short glass tubes to adjust the positions of the drops of coloured water near the elbows of the capillary tubes.

4. Place the light source 20 cm away from the tubes, and measure the rate of photosynthesis. Readjust the coloured drops and repeat the measurements.

5. Pour out the liquid in each test tube, and refill them with fresh carbonate solution.

6. Repeat the experiment with solutions of different concentration of the carbonate.



Observation Table:

Concentration of carbonate	Rate of Movement of Coloured Drop with *Elodea*	without *Elodea*	Difference
0.5%			
1.0%			
5.0%			

Questions:

1. What relationship can you establish from your data between the rate of photosynthesis and the concentration of carbonate?

2. What would you have to do to convert your relative measurements into absolute quantities of oxygen produced in a specific time interval?

3. Name one other factor affecting the rate of photosynthesis you could investigate with some modification of the set up you used in this experiment.
Describe the modification you would use.

Response/Marking Scheme

Experimental Technique	5
Results	4

Answers to Questions

1. There appears to be a direct relationship between the concentration and the rate of photosynthesis; 1
   the more concentrated the carbonate, the faster the rate. 2
2. Measure the volume of the bore of the capillary tube 1
   by displacing gas through the system 1
   from the pipette. 1
3. Answers will vary. Some acceptable responses:
   Wave length (quality) of light 1
   Use coloured filters on the light source 1
   or

   Intensity of light Move light source to different measured distances from the plant
   or

   Temperature Surround test tube with a water bath and control temperatures through a range such as $5^{\circ} - 35^{\circ}C$.

Possible: 17

Maximum: 15

Teacher Notes

1. In this activity, the rate of photosynthesis is indicated by the pressure of the oxygen released by a sprig of water plant. The pressure is measured using a manometer. A control tube is set up without a plant.

2. Different lab teams could be assigned a variety of conditions to try: using coloured filters to investigate the effects of different wave lengths (quality), or controlling the temperature of the water bath with ice or heat.

3. Advance preparation: let tap water stand for 2 days for the chlorine to escape. Prepare the hydrogen carbonate solution.

   Materials: (per team of 2 students)

1	beaker, 600 mL
2	test tubes, 20 x 150 mm
2	syringes, 1 mL
2	stoppers, 2 - holed to fit test tubes (#6)
2	adjustable clamps
2	short glass tubes with rubber sleeves
2	capillary tubes, bent at 90°
1	metre stick
1	light source (100 W bulb in an upright lamp, or fluorescent growth lamps)
	Elodea or other suitable water plant

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLE.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.8, B.1, B.3, B.4, D.1, D.2, D.3, D.5, D.6
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: temperature lab

Guideline Objective

Students will have the opportunity to develop skill in designing and performing experiments to study the effects on the rate of photosynthesis and performing experiments to study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature, and quality and intensity of light.

Item Focus

The students should be able to perform an experiment to show the effects of the temperature on the rate of photosynthesis.

Item

This laboratory activity is designed to let you determine the rate of photosynthesis of a plant by measuring the rate at which oxygen is released. This is most easily done with a plant that lives under water: *Elodea*. Since oxygen is not very soluble in water, it is set free from the cut ends of the stems as bubbles of gas. The increase in pressure due to the released gas will drive a drop of coloured liquid along the capillary tube. The rate at which the drop moves is used as an estimate of the rate of photosynthesis. You will investigate the relationship between temperature and the rate of photosynthesis. Procedure:

1. Set up the apparatus as shown in Figure 3.1. Use the syringe to introduce a drop of water with vegetable colouring into the capillary tubes. Fill the test-tubes to within 5 mm of the stopper with the sodium hydrogen carbonate solution.

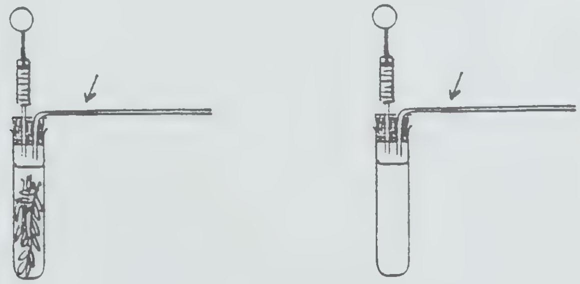
2. Cut the stems of 2 or 3 tips of healthy *Elodea* sprigs, about 8 cm long. Place the *Elodea* stems into one test tube, with their cut ends at the top.

3. Place the 2-holed stoppers into the test tubes. Use the syringes in the short glass tubes to adjust the positions of the drops of coloured water near the elbows of the capillary tubes. Immerse the test tubes into a water bath at room temperature. Record the temperature of the water bath.

4. Place the light source 20 cm away from the tubes, and measure the rate of photosynthesis. Readjust the coloured drops and repeat the measurements.

5. Pour out the liquid in each test tube, and refill them with the carbonate solution. Warm the water in the water bath to 30°C and repeat the experiment.

6. Repeat the experiment with ice water in the water bath.



Observation Table:

Temperature of carbonate solution	Rate of Movement of Coloured Drop with *Elodea*	without *Elodea*	Difference
°C			
°C			
°C			

Questions:

1. Use your data to graph the relationship between the rate of photosynthesis and the temperature.

2. What would you have to do to convert your relative measurements into absolute quantities of oxygen produced in a specific time interval?

3. Name one other factor affecting the rate of photosynthesis you could investigate with some modification of the set up you used in this experiment. Describe the modification you would use.

Response/Marking Scheme

Experimental Technique	5
Results	4
<u>Answers to Questions</u>	

1. Graph — 3
2. Measure the volume of the bore of the capillary tube — 1
   by displacing gas through the system — 1
   from the pipette. — 1
3. Answers will vary. Some acceptable responses:
   Wave length (quality) of light — 1
   Use coloured filters on the light source — 1

   or

   Concentration of carbonate solution (carbon dioxide) — (1)
   Use solutions that are more (or less) concentrated in sodium hydrogen carbonate, say 5% or 0.5% — (1)

   or

   Light Intensity — (1)
   Vary the distance between the light source and the water plants. — (1)

Possible: 17

Maximum: 15

Teacher Notes

1. In this activity, the rate of photosynthesis is indicated by the pressure of the oxygen released by a sprig of water plant. The pressure is measured using a manometer. A control tube is set up without a plant.

2. Different lab teams could be assigned a variety of conditions to try: using coloured filters to investigate the effects of different wave lengths (quality), or controlling the temperature of the water bath with ice or heat.

3. Advance preparation: let tap water stand for 2 days for the chlorine to escape. Prepare the hydrogen carbonate solution.

   Materials: (per team of 2 students)

   1 beaker, 600 mL
   2 test tubes, 20 x 150 mm
   2 syringes, 1 mL
   2 stoppers, 2 - holed to fit test tubes (#6)
   2 adjustable clamps
   2 short glass tubes with rubber sleeves
   2 capillary tubes, bent at 90°
   1 metre stick
   1 light source (100 W bulb in an upright lamp, or fluorescent growth lamps)
   Elodea or other suitable water plant
   water bath: temperature range such as 5° – 35°C

   ice water

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLE.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.8, B.1, B.3, B.4, D.1, D.2, D.3, D.5, D.6
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light intensity lab

Guideline Objective

Students will have the opportunity to develop skill in designing and performing experiments to study the effects on the rate of photosynthesis and performing experiments to study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature, and quality of light.

Item Focus

The students should be able to perform an experiment to show the effects of the quality or intensity of light on the rate of photosynthesis.

Item

This laboratory activity is designed to let you determine the rate of photosynthesis of a plant by measuring the rate at which oxygen is released. This is most easily done with a plant that lives under water: *Elodea*. Since oxygen is not very soluble in water, it is set free from the cut ends of the stems as bubbles of gas. The increase in pressure due to the released gas will drive a drop of coloured liquid along the capillary tube. The rate at which the drop moves is used as an estimate of the rate of photosynthesis.

Procedure:

1. Set up the apparatus as shown in Figure 3.1. Use the syringe to introduce a drop of water with vegetable colouring into the capillary tubes. Fill the test-tubes to within 5 mm of the stopper with the sodium hydrogen carbonate solution.

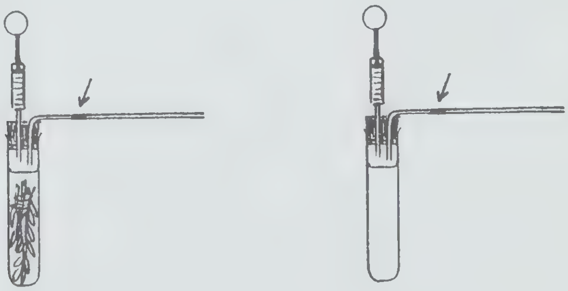
2. Cut the stems of 2 or 3 tips of healthy *Elodea* sprigs, about 8 cm long. Place the *Elodea* stems into one test tube, with their cut ends at the top.

3. Place the 2-holed stoppers into the test tubes. Use the syringes in the short glass tubes to adjust the positions of the drops of coloured water near the elbows of the capillary tubes.

4. Place the light source 20 cm away from the tubes, and measure the rate of photosynthesis. Readjust the coloured drops and repeat the measurements.

5. Pour out the liquid in each test tube, and refill them with fresh carbonate solution. Move the light source to 40 cm from the tubes, and repeat the measurements.

6. Repeat the experiment with the light source 60 cm from the tubes.



Observation Table:

Distance from light source	Rate of Movement of Coloured Drop with *Elodea*	without *Elodea*	Difference
20 cm			
40 cm			
60 cm			

Questions:

1. What mathematical relationship can you establish from your data between the rate of photosynthesis and the distance from the light source?

2. What would you have to do to convert your relative measurements into absolute quantities of oxygen produced in a specific time interval?

3. Name one other factor affecting the rate of photosynthesis you could investigate with some modification of the set up you used in this experiment.
Describe the modification you would use.

Response/Marking Scheme

Experimental Technique	5
Results	4

<u>Answers to Questions</u>

1. There appears to be a direct relationship between the square of the distance and rate of photosynthesis; 1
   at twice the distance, the rate of photosynthesis is one-quarter, 1
   and at thrice the distance, the rate is one-ninth. 1
2. Measure the volume of the bore of the capillary tube 1
   by displacing gas through the system 1
   from the pipette. 1
3. Answers will vary. Some acceptable responses: Wave length (quality) of light 1
   Use coloured filters on the light source 1

   or

   Concentration of carbon dioxide/carbonate solution. Use solutions with greater or lesser concentrations of carbonate.

   or

   Temperature Surround test tube with a water bath and control temperatures through a range such as $5° - 35°C$.

Possible: 17

Maximum: 15

Teacher Notes

1. In this activity, the rate of photosynthesis is indicated by the pressure of the oxygen released by a sprig of water plant. The pressure is measured using a manometer. A control tube is set up without a plant.

2. Different lab teams could be assigned a variety of conditions to try: using coloured filters to investigate the effects of different wave lengths (quality), or controlling the temperature of the water bath with ice or heat.

3. Advance preparation: let tap water stand for 2 days for the chlorine to escape. Prepare the hydrogen carbonate solution.

Materials: (per team of 2 students)

1	beaker, 600 mL
2	test tubes, 20 x 150 mm
2	syringes, 1 mL
2	stoppers, 2 - holed to fit test tubes (#6)
2	adjustable clamps
2	short glass tubes with rubber sleeves
2	capillary tubes, bent at 90°
1	metre stick
1	light source (100 W bulb in an upright lamp, or fluorescent growth lamps)
	Elodea or other suitable water plant

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLP.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.4, A.10, C.2, C.3, C.4
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis.

Guideline Objective

Students will have the opportunity to develop skill in performing experiments to i) study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature and light, or ii) analyse the characteristics of photosynthetic pigments in an extract from leaf tissue.

Item Focus

Same as above.

Item

Design an experiment to investigate whether carbon monoxide, a gas produced during combustion (and present in automobile exhaust), has any effect on photosynthesis. State clearly the hypothesis you would be testing.

Response/Marking Scheme

The response should include each of the following:

1. Hypothesis: a clear statement. 2
2. Establishing a control: some plants not treated with carbon monoxide, but undergoing all the same growing conditions as the treated plants. 2
3. Replicates: a number of replicates for both treated and untreated plants. 2
4. A method: including a source of carbon monoxide, 9
   a way to control its administration, and a test: factors that might be examined to determine whether carbon monoxide has any effect. 3

Possible: 18

Maximum: 15

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031ScLP.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sc Photosynthesis
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.7, A.10, C.3, F.1
TOPIC: Conditions Affecting Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Practical Application	TIME ALLOCATION:

KEYWORDS: carbon dioxide concentration

Guideline Objective

Students will have the opportunity to develop skill in designing and performing experiments to study the effects on the rate of photosynthesis of variations in one or more of carbon dioxide concentration, temperature and quality and intensity of light.

Item Focus

The student should be able to identify various factors in a plant's environment, and explain how each may affect the rate of photosynthesis.

Item

A grower noticed a problem with the plants in one green house. The plants looked healthy, but they were not growing at the same rate as apparently identical plants in other greenhouses. The grower called in a plant scientist to solve the problem. She tested the following conditions: light, temperature, soil nutrients. None showed any significant effect.

What other factors might she test, and how would each of these affect growth?

Response/Marking Scheme

1. Carbon dioxide levels: 1

   If the carbon dioxide level is not adequate, the rate of carbon fixation will be reduced, and the plant will not be able to increase in mass at the same rate. 2

2. Genetic strain of the seeds: 1

   If the seeds are of a different strain from those in the other greenhouses, the plants may be genetically inferior, and may not have the same vigorous cell machinery to promote rapid growth. 2

3. Presence of sufficient water in the soil or atmosphere 1

   If the amount of water in the soil is inadequate, the stomata will close, limiting the access of carbon dioxide to the interior of the leaves, and restricting the rate of photosynthesis. Water is also necessary for the light reaction, as the source of hydrogen and electrons; When water is limiting, photosynthesis cannot occur. 1

Possible: 9

Maximum: 6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYHTHESIS	KLOPFER: A.1, A.3, A.5, D.3, D.6
	DIFFICULTY LEVEL: M
TOPIC: Photosynthesis	TIME ALLOCATION:
CURRICULAR EMPHASIS: Nature of Science	

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

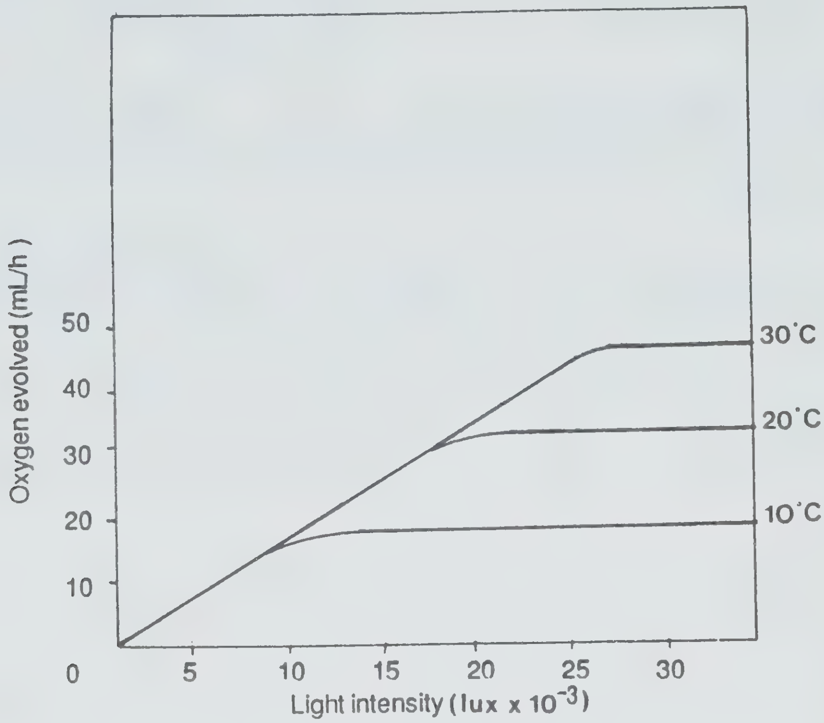
Item Focus

The same as above.

Item

Refer to Figure 3S.4.

RATE OF PHOTOSYNTHESIS IN CORN (ZEA MAYS)



With the aid of the graph in Figure 3S.4, evaluate the following statement:

"Light and temperature are the only factors which influence the rate of photosynthesis."

☐ A. The statement is correct and can be determined from the data.

☐ B. The statement is correct but can <u>NOT</u> be determined from the data.

☐ C. The statement is incorrect and can be determined from the data.

☐ D. The statement is incorrect but can <u>NOT</u> be determined from the data.

Response/Marking Scheme

Correct response: D

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

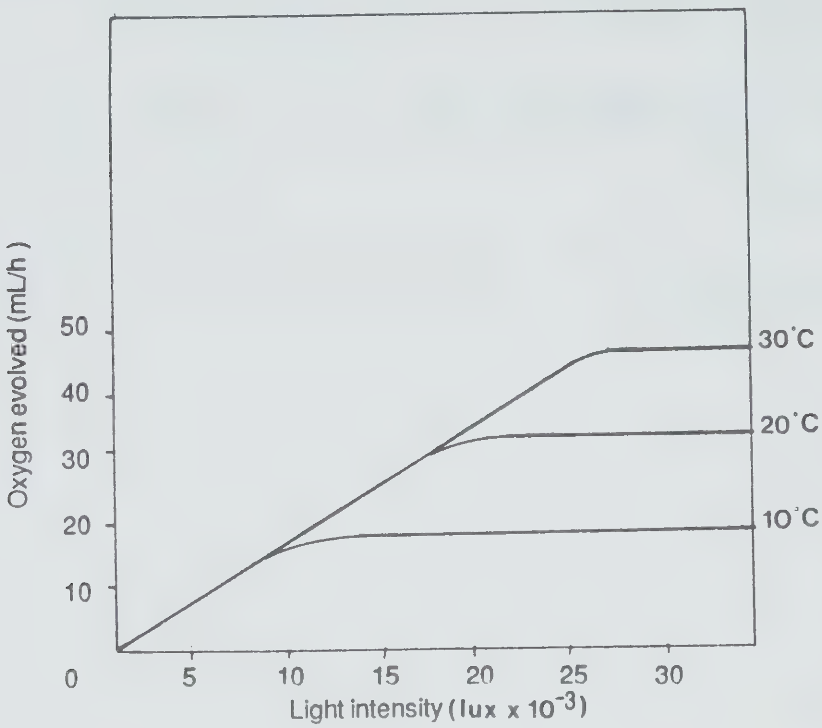
Item Focus

The same as above.

Item

Refer to Figure 3S.4.

RATE OF PHOTOSYNTHESIS IN CORN (ZEA MAYS)



With the aid of the graph in Figure 3S.4, evaluate the following statement:

"The rate of photosynthesis can be determined by measuring the oxygen released."

☐ A. The statement is correct and can be determined from the data.

☐ B. The statement is correct but can <u>NOT</u> be determined from the data.

☐ C. The statement is incorrect and can be determined from the data.

☐ D. The statement is incorrect but can <u>NOT</u> be determined from the data.

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

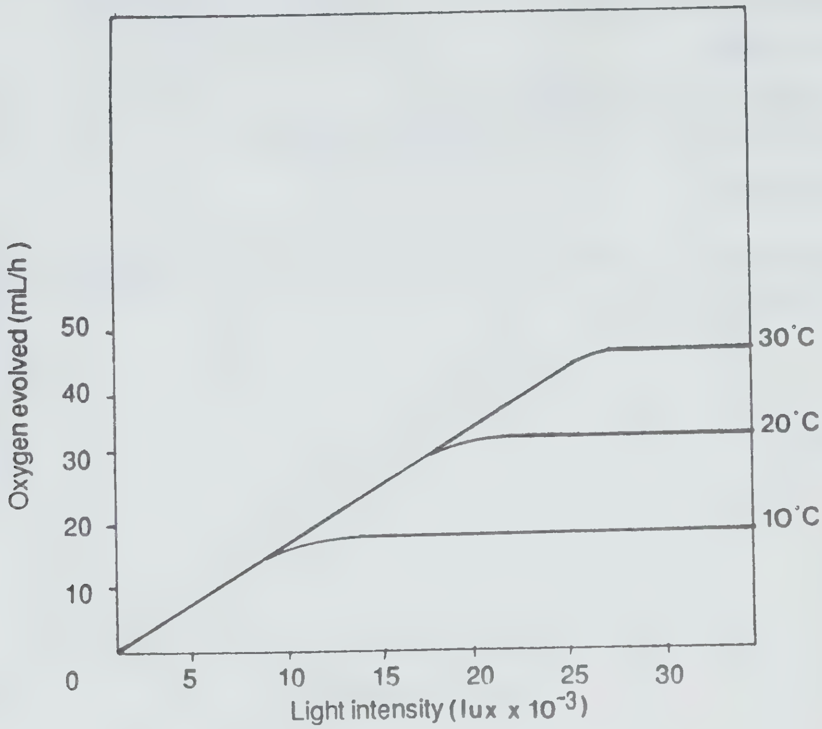
Item Focus

The same as above.

Item

Refer to Figure 3S.4.

RATE OF PHOTOSYNTHESIS IN CORN (ZEA MAYS)



With the aid of the graph in Figure 3S.4, evaluate the following statement:

> "At low light intensities, an increase in the temperature will increase the rate of photosynthesis."

☐ A. The statement is correct and can be determined from the data.

☐ B. The statement is correct but can <u>NOT</u> be determined from the data.

☐ C. The statement is incorrect and can be determined from the data.

☐ D. The statement is incorrect but can <u>NOT</u> be determined from the data.

Response/Marking Scheme

Correct answer: C

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

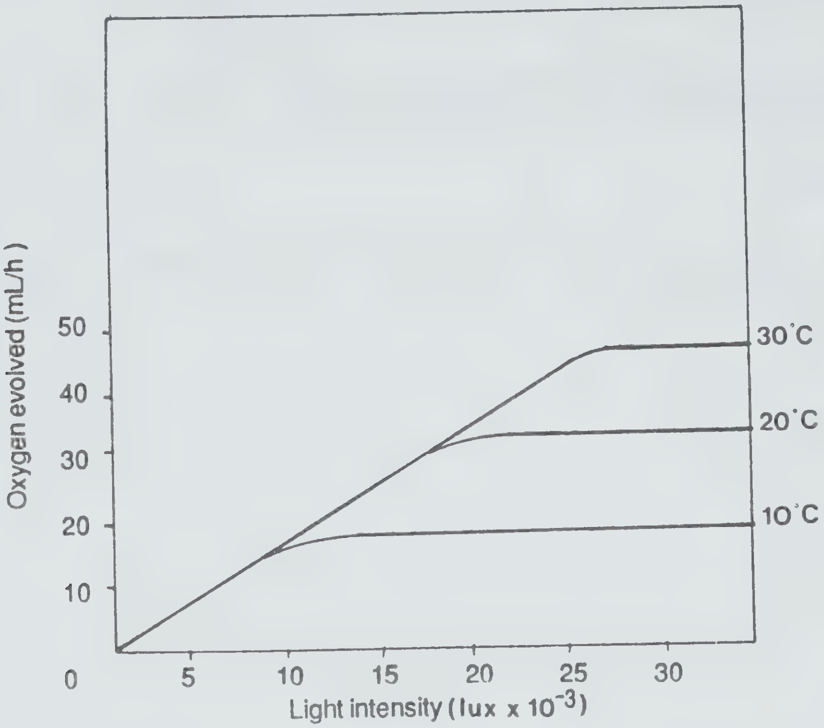
Item Focus

The same as above.

Item

Refer to Figure 3S.4.

RATE OF PHOTOSYNTHESIS IN CORN (ZEA MAYS)



With the aid of the graph in Figure 3S.4, evaluate the following statement:

> "High temperatures only affect the rate of photosynthesis at high light intensities."

☐ A. The statement is correct and can be determined from the data.

☐ B. The statement is correct but can NOT be determined from the data.

☐ C. The statement is incorrect and can be determined from the data.

☐ D. The statement is incorrect but can NOT be determined from the data.

Response/Marking Scheme

Correct response: A

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

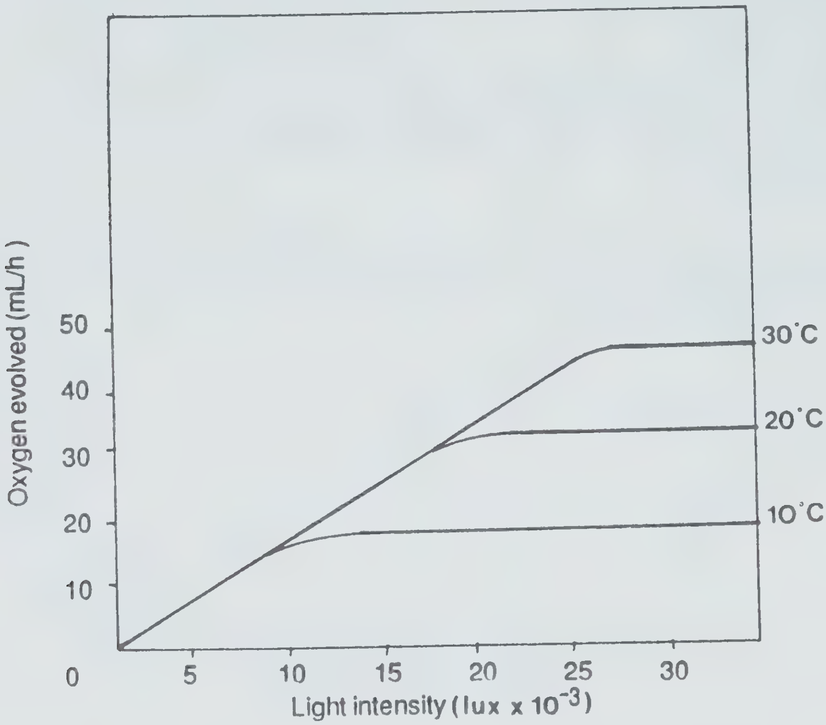
Item Focus

The same as above.

Item

Refer to Figure 3S.4.

RATE OF PHOTOSYNTHESIS IN CORN (ZEA MAYS)



With the aid of the graph in Figure 3S.4, evaluate the following statement:

"The higher the temperature, the higher the rate of photosynthesis."

☐ A. The statement is correct and can be determined from the data.

☐ B. The statement is correct but can <u>NOT</u> be determined from the data.

☐ C. The statement is incorrect and can be determined from the data.

☐ D. The statement is incorrect but can <u>NOT</u> be determined from the data.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdMC.07
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
TOPIC: Conditions Affecting Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis aerobic respiration graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3S.5.

INTERACTION OF PHOTOSYNTHESIS AND RESPIRATION IN PLANTS

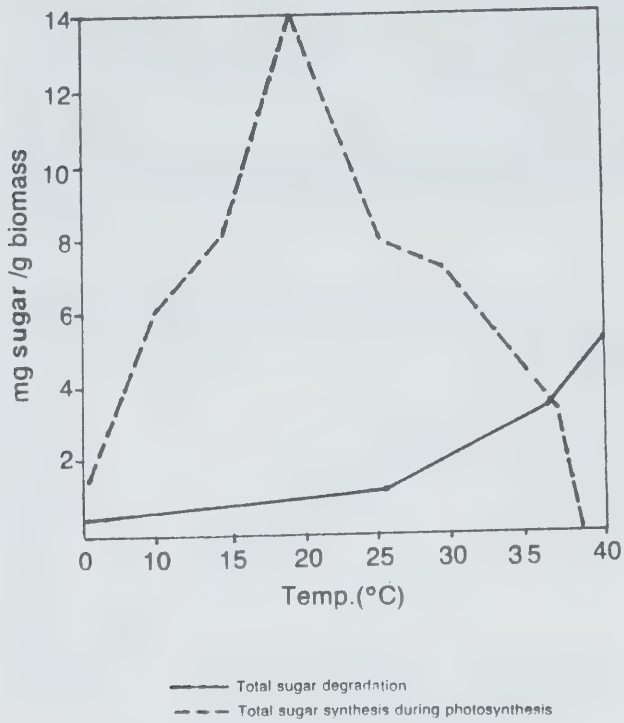


Figure 3S.5 represents the interaction of photosynthesis in full sunlight and respiration in plant cells. The cells would eventually die if the temperature were kept

☐ A. at 5°C

☐ B. above 20°C

☐ C. above 24°C

☐ D. above 30°C

☐ E. above 37°C

Response/Marking Scheme

Correct answer: E

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.7, A.10, D.1, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

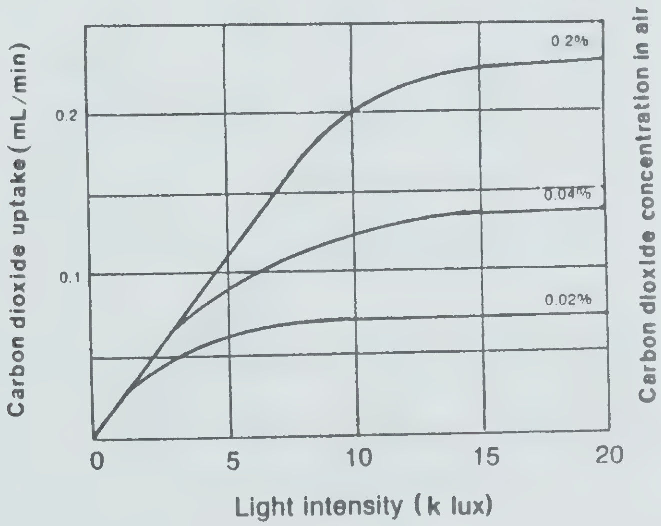
Item Focus

The student should be able to interpret data from experiments on photosynthesis from a graph.

Item

Refer to Figure 3S.6.

FACTORS AFFECTING THE RATE OF PHOTOSYNTHESIS



A. Summarize the data shown in Figure 3S.6.

B. What single major interpretation can be drawn from the data?

Response/Marking Scheme

A.	The graph shows the effects on the rate of photosynthesis (measured by	1
	carbon dioxide uptake) of varying both the light intensity and concentration of carbon dioxide in the atmosphere. From the graph it appears that as the light intensity and/or concentration of carbon dioxide in the atmosphere increases, so does	2
	the rate of photosynthesis, to a certain point at which the rate stops increasing.	1
	At increased concentrations of	1
	carbon dioxide, the rate of photosynthesis is higher and	1
	the rate stops increasing at a higher light intensity.	1
B.	This indicates that the factor which becomes limiting is light independent.	3
	Possible:	10
	Maximum:	7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.7, A.19, D.1, D.3, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

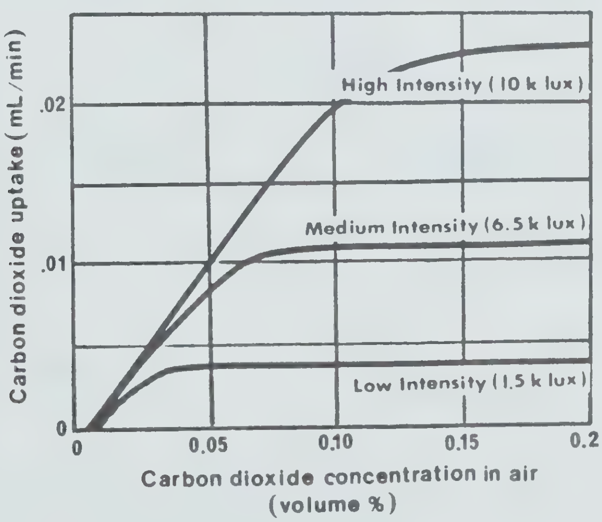
Item Focus

The student should be able to interpret data from experiments on photosynthesis from a graph.

Item

Refer to Figure 3S.7.

FACTORS AFFECTING THE RATE OF PHOTOSYNTHESIS



A. Summarize the data shown in Figure 3S.7.

B. What single major interpretation can be drawn from the data?

Response/Marking Scheme

A. In the figure, the rate of photosynthesis (measured by the rate of carbon dioxide uptake) at different concentrations of carbon dioxide, is examined at three distinct light intensities. 1

The rate of photosynthesis is greater at higher light intensities. 1

This is true at all levels of carbon dioxide in atmosphere that was examined. 1

As the percentage of carbon dioxide in the atmosphere increased, the rate increased for each of the light intensities, to a point which varied for each light intensity. At this point, the rate of photosynthesis stopped increasing and levelled off. 1

The lower the light intensity the lower the percentage of carbon dioxide in the atmosphere at which the rate stops increasing. 1

B. It seems that at lower light intensities, some factor, other than carbon dioxide, becomes limiting. 3

Possible: 8

Maximum: 6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B031SdLA.03R
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: LA
KLOPFER: A.1, A.2, A.3, A.9, B.2, D.2, D.3, D.6
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: light-dependent reactions light-independent reactions phosphoglyceric acid ribulose diphosphate

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3S.8.

EFFECTS OF REMOVAL OF CARBON DIOXIDE ON PHOTOSYNTHETIC INTERMEDIATES

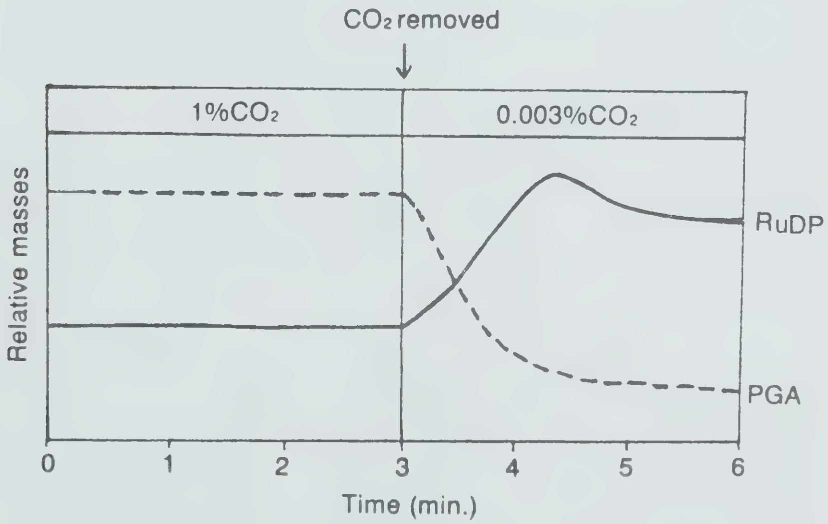


Figure 3S.8 shows changes (in a qualitative way) that occur in the amounts of ribulose diphosphate (RuDP) and phosphoglyceric acid (PGA) in leaf mesophyll cells during a six minute interval with the concentration of carbon dioxide being suddenly diminished at the middle of the interval. Using your knowledge of photosynthesis, account for the changes that occur in the graphs.

Response/Marking Scheme

RuDP would normally join with carbon dioxide, forming a six-carbon complex	1
that rearranges and cleaves to form two molecules of PGA.	1
With less carbon dioxide present,	1
this reaction is prevented,	1
so RuDP builds up initially.	1
Apparently, the acccumulation of RuDP encourages a reaction to divert RuDP into synthesis of a different product	1
(e.g., glycine or glycollic acid)	1
so the amount of RuDP decreases after the fourth minute.	1
Meanwhile, ATP and reduced NADP continue to be supplied by the light-dependent reactions	1
so PGA is being withdrawn by being reduced to phosphoglyceraldehyde.	1
This withdrawn PGA cannot be replaced without carbon dioxide so the amount of PGA decreases.	2
Possible:	12
Maximum:	8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A1, A2, A3, A9, B2, D2, D3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light-dependent reactions light-independent reactions graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Objective as above.

Item

Refer to Figure 3S.9.

EFFECTS OF REMOVAL OF LIGHT ON
PHOTOSYNTHETIC INTERMEDIATES

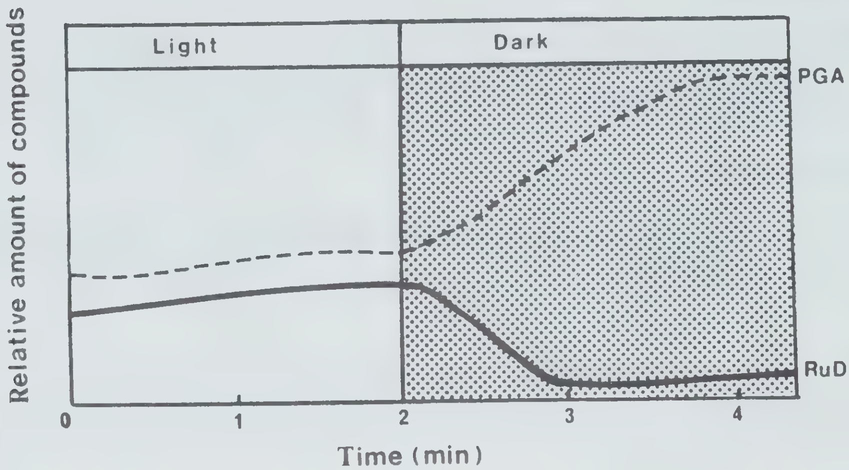


Figure 3S.9 shows, in a qualitative way, how the amounts of phosphoglyceric acid (PGA) and ribulose diphosphate (RuDP) change in photosynthesizing cells over a 4.5 min period. The cells were illuminated for 2 min and then kept in darkness.

A. Describe the data presented on the graph.

B. Explain the shapes of the curves in terms of photosynthesis.

Response/Marking Scheme

A.	In the light, the two curves are parallel. In the dark, the amount of RuDP falls quickly to a low level, while the amount of PGA rises, though not as quickly. Both substances stabilize at their new levels.	3
B.	When light is withdrawn, there is rapid depletion	1
	of ATP and of reduced NADP,	2
	both of which are generated using the energy of light.	1
	The lack of ATP	1
	prevents the conversion of ribulose monophosphate into	1
	ribulose diphosphate.	1
	At the same time, since the combination of carbon dioxide with ribulose diphosphate requires no energy input,	1
	therefore, RuDP, present before illumination was withdrawn, is used up	1
	so the quantity of RuDP decreases.	1
	The lack of reduced NADP	1
	prevents the reduction of phosphoglyceric acid to phosphoglyceraldehyde	1
	so PGA accumulates.	1
	Since PGA builds up at a slower rate than RuDP decreases,	1
	it is likely that the combination of carbon dioxide with RuDP is a much faster reaction than the rearrangement and cleavage of the six-carbon intermediate, so formed, to form PGA.	1

Possible: 17

Maximum: 12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.1, D.2, D.3
TOPIC: Conditions Affecting Photosynthesis.	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

The student should be able to draw and interpret graphs of experimental data.

Item

Plants of the same species were kept in the dark for 48 h. They were then maintained at a range of temperatures under two different intensities of light.

After a period of 48 hours, the plants were examined for the amount of sugar present in the leaf matter and the following results were obtained:

TEMPERATURE (^oC)	PARTIAL SHADE (mg sugar synthesized/g biomass during photosynthesis)	FULL SUNLIGHT
5	1.2	1.3
10	3.2	6.0
15	4.2	7.8
20	4.3	13.3
25	3.3	8.0
30	2.0	6.3
35	0	3.8
40	0	0

A. Why were the plants kept in the dark before the experiment?

B. Graph the above results.

C. Describe and interpret the results with respect to photosynthesis and the action of enzymes in the plant.

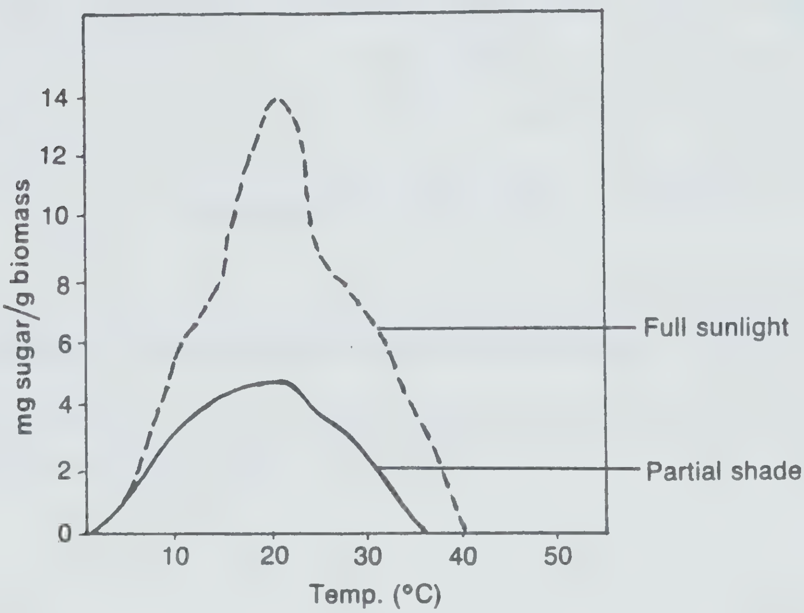
Response/Marking Scheme

A. To reduce their sugar content to a common base line. 2

B.

THE EFFECT OF TEMPERATURE ON SUGAR SYNTHESIS

IN FULL SUNLIGHT AND PARTIAL SHADE 1



orientation of axes 1

labelling 2

graphs 2

C. From the information provided in the chart, it is apparent that in both full sunlight and partial shade, there is a production of sugar. 1

In both these conditions, the graphs have similar shapes, with the maximum occuring at approx. 20^oC. 1

Approximately 3 times as much sugar is synthesized under conditions of full sunlight as partial shade. 1

The enzymes involved are the same in both conditions and reach their maximum efficiency at approximately the same temperature. 1

The synthesis of sugar stops at a lower temperature in partial shade because light becomes a limiting factor. 1

At higher temperatures, in both conditions, the synthesis decreases due to a degradation of enzymes. 1

Possible: 14

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Conditions Affecting Photosynthesis.
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031SdLA.06
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: LA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.1, D.2, D.3
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: photosynthesis aerobic respiration graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

The student should be able to draw and interpret graphs of experimental data.

Item

Plants of the same species were kept in the dark for 48 h. They were then maintained at a range of temperatures under two different intensities of light.

After a period of 48 hours, the plants were examined for the amount of sugar present in the leaf matter and the following results were obtained:

TEMPERATURE (^oC)	TOTAL DARKNESS (mg sugar degraded per g biomass)	FULL SUNLIGHT (mg sugar synthesized per g biomass)
5	0.5	1.3
10	0.5	6.0
15	0.6	7.8
20	0.7	13.3
25	0.9	8.0
30	2.2	6.3
35	3.1	3.8
40	3.8	0
45	4.2	0
50	5.6	0

A. Why were the plants kept in the dark before the experiment?

B. Graph the above results.

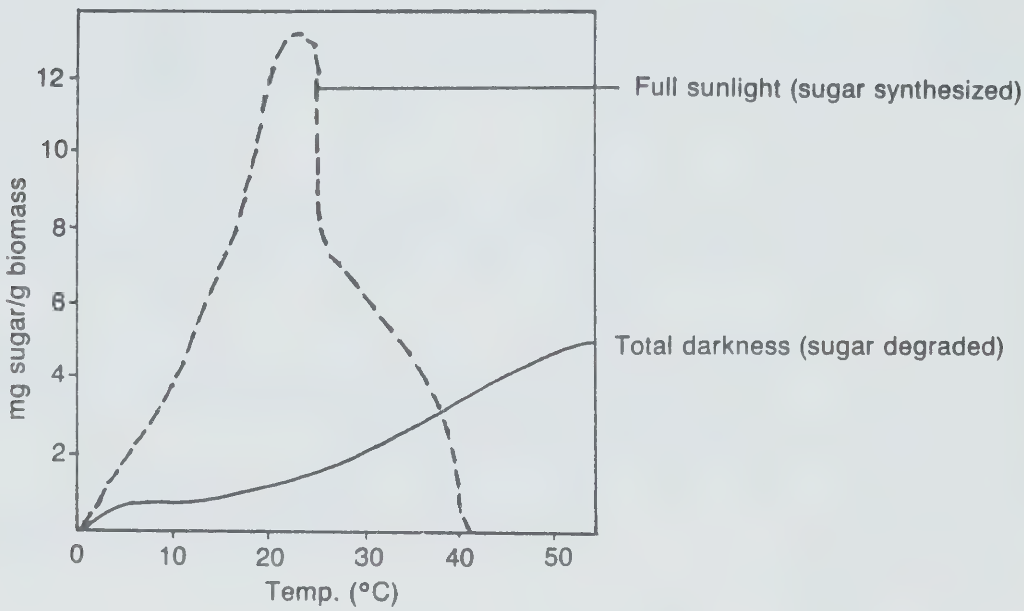
C. Describe and interpret the results with respect to photosynthesis in the plant.

Response/Marking Scheme

A. To reduce their sugar content to a common base line. 2

B.

THE EFFECT OF TEMPERATURE ON SUGAR SYNTHESIS AND RESPIRATION IN FULL SUNLIGHT AND IN TOTAL DARKNESS 1



orientation of axes 1

labelling 2

graphs 2

C. Sugar is produced in the light, while it is degraded in the dark. 1

The reason for this is that in the dark, there is no energy available for photosynthesis, so no sugar is being synthesized. Respiration is occuring all the time and sugar is being broken down for the plant's metabolism. 1

Both graphs rise because both of these processes are the result of enzyme action. 1

The enzymes in both photosynthesis and respiration increase in efficiency with increasing temperature 1

to a maximum, until the temperature begins to denature the enzymes involved. 1
Because different enzymes are involved in the two processes, the peak occurs for photosynthesis at 20^oC, while the curve for respiration continues to rise. 1

Possible: 14

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.07
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.1, D.2, D.3
TOPIC: Conditions Affecting Photosynthesis.	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

The student should be able to draw and interpret graphs of experimental data.

Item

Plants of the same species were kept in the dark for 48 h. They were then maintained at a range of temperatures under two different intensities of light.

After a period of 48 hours, the plants were examined for the amount of sugar present in the leaf matter and the following results were obtained:

TEMPERATURE (°C)	PARTIAL SHADE mg sugar synthesized per g biomass	FULL SUNLIGHT mg sugar synthesized per g biomass
5	1.2	1.3
10	3.2	6.0
15	4.2	7.8
20	4.3	13.3
25	3.3	8.0
30	2.0	6.3
35	0	3.8
40	0	0
45	0	0

A. Why were the plants kept in the dark before the experiment?

B. Graph the above results.

C. Describe and interpret the results with respect to photosynthesis in the plant.

D. Why does the plant in partial shade stop synthesizing sugar before the plant in full sunlight?

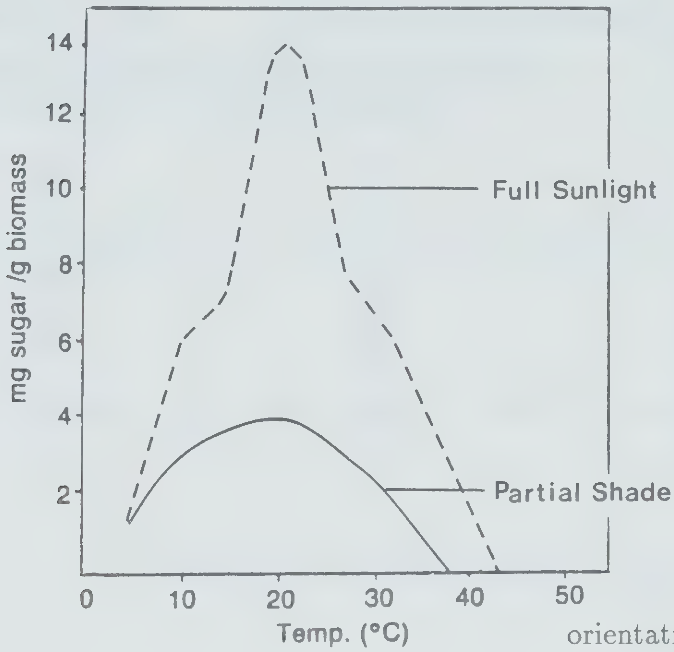
E. Explain the fact that, although the graphs are different, they both have a similar starting point.

Response/Marking Scheme

A. To reduce their sugar content to a common base line. 2

B.

THE EFFECT OF TEMPERATURE ON SUGAR SYNTHESIS IN FULL SUNLIGHT AND PARTIAL SHADE 1



orientation of axes 1
labelling 2
graphs 2

C. The plant in full sunlight attains a higher maximum than that in partial shade because of the higher light intensity. 1

The less light, the less energy is available for the fixation of carbon dioxide. 1

D. The plant in partial shade synthesizes less sugar than the plant in full sunlight because the plant in partial shade has less carbon fixation actually occurring, 2

E. Although the plants in partial shade and full sunlight carry on the synthesis at different rates, the same reactions are occurring, so the graphs begin together. 2

Possible: 14

Maximum: 10

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLA.08
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd Photosynthesis
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.1, D.3
TOPIC: Conditions Affecting Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: aerobic respiration graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3S.13.

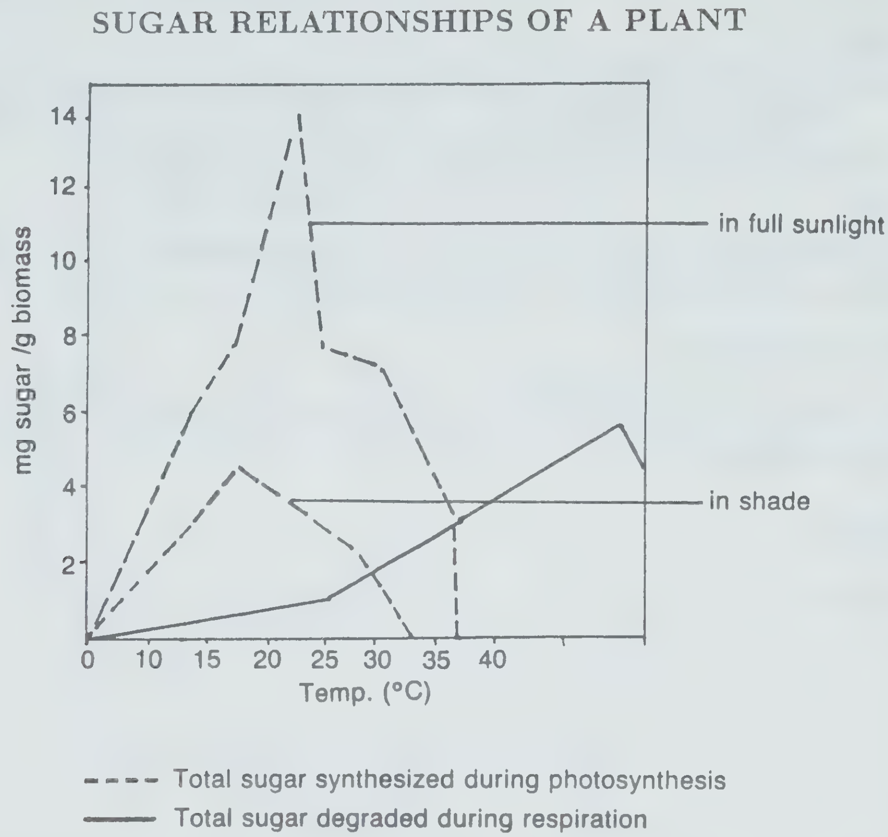


Figure 3S.13 represents the sugar relationships of a plant under different conditions. For all the conditions, explain

A. why the curves rise to a peak.

B. why the curves fall after peaking.

C. why the curves for respiration peak at different temperatures from those for photosynthesis.

Response/Marking Scheme

A. All curves show a rise because with the increasing temperatures, the activity of the enzymes involved increases. 1

This allows more sugar to be either synthesized or degraded, depending on which curve is being examined. 1

B. Likewise, each curve experiences a decline due to the fact that as the temperature continues to increase the enzymes begin to be denatured, 1

causing a decrease in the activity of either sugar synthesis or degradation. 1

C. Both processes are affected by temperature, but they represent activity of different enzymes which are suited to different temperatures. 2

Possible: 6

Maximum: 6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031SdLA.09
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: LA
KLOPFER: A.1, A.2, A.3, A.10, D.1, D.2, D.3, D.6
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: chlorophyll chloroplasts radioactive isotope graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

The student should be able to draw and interpret a graph of laboratory data.

Item

In an experiment, isolated chloroplasts were allowed to photosynthesize using radioactively labelled carbon dioxide. This experiment was carried out both in light and in dark conditions. The following results were obtained:

TIME (min)	CARBON DIOXIDE ASSIMILATED (units/min)	
	LIGHT	DARK
0	0	0
10	30	2
20	17	2
30	22	3
40	41	3
50	56	4
60	71	4

A. Graph the results obtained.

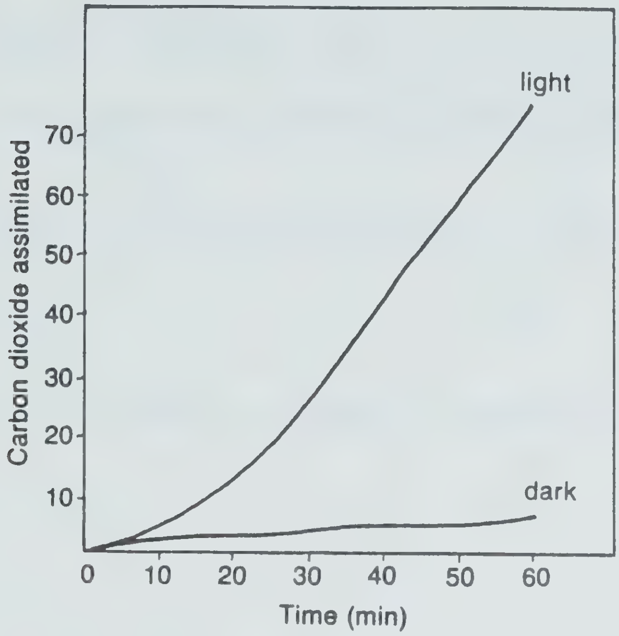
B. Interpret the results in terms of the mechanics of photosysnthesis.

Response/Marking Scheme

A. Title 1

ASSIMILATION OF CARBON DIOXIDE

BY ISOLATED CHLOROPLASTS IN LIGHT AND DARK



Axes 1
Labelling 2
Graph 1

B. From the results obtained, both plants incorporate some of the labelled carbon dioxide. 1

The plant in the light assimilates an increasingly higher amount, where the plant in the dark assimilates very little. 1

The reason for this is that the plant in the light is constantly converting more chemical energy (ATP, NADPH and H^+), 1

used for the process of carbon fixation. 1

The plant in the dark assimilates carbon dioxide until it runs out of available chemical energy, then stops. 1

Possible: 11

Maximum: 10

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLP.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1,A.2,A.5,A.7,A.8,B.2,D.1 - 4, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

The student should be able to interpret and graph data obtained from an experiment on photosynthesis.

Item

Problem: What is the effect of varying light intensities on photosynthesis in the green alga, *Chlorella*?

To investigate the problem, *Chlorella* was placed in a closed system, and its rate of production of gas was measured at varying light intensities. The results are shown in the table, below.

You will have 20 min to graph, analyze, and interpret the data to answer the problem.

LIGHT INTENSITY	GAS PRODUCED
klux	mL/h
0	20
1	25
2	31
3	35
4	48
5	52
6	71
7	80
8	94
9	109
10	121

Response/Marking Scheme

Graphing of data:

Axes properly oriented and labelled	4
Points and curve correctly drawn	1
Analysis: The greater the light intensity, the greater the volume of gas produced.	1
Interpretation:	
With zero light intensity, the gas produced must be carbon dioxide, from respiration.	2
As light intensity increases, oxygen is produced by photosynthesis.	2
Between 4 and 5 klux, there is a very small increase in gas; this must be the compensation point, where respiration and photosynthesis are in balance, and any gas produced in one of the processes is used for the other.	2
Possible:	12
Maximum:	10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLP.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, A.10, C.1, D.1 - 4, D.6, E.2, F.1, I.4
TOPIC: Conditions Affecting Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Practical Application	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis herbicide.

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

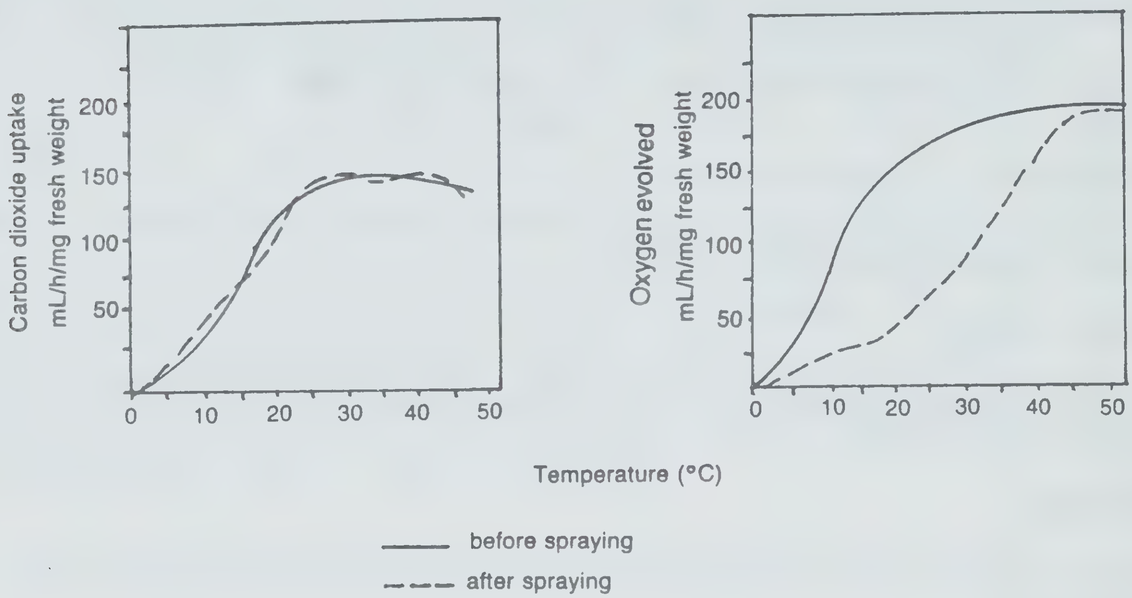
Item Focus

The student should be able to interpret graphs of data obtained from experiments with photosynthesis.

Item

Refer to Figure 3S.15.

EFFECT OF A HERBICIDE ON RATE OF PHOTOSYNTHESIS



Scientists testing the effects of a new herbicide on the rates of photosynthesis in plants produced the graphs shown in Figure 3S.15.

A. In what ways does the new herbicide appear to be affecting photosynthesis? Explain your hypotheses.

B. What might be the effect of the herbicide on a crop that was sprayed with it?

Response/Marking Scheme

A.	The rate of photosynthesis is low at low temperatures in all 4 curves, increasing with temperature to a plateau.	1
	The effect of spraying shows most markedly on the curve of oxygen release. There is negligible effect on the uptake of carbon dioxide.	2
	This suggests that the herbicide does not affect the enzymes of the carbon fixation cycle,	2
	but does affect the enzymes concerned with photophosphorylation.	2
B.	The herbicide would cause a reduction in biomass,	1
	particularly at temperatures below 25°C.	1
	If the crop were growing in a cool season, this could have a significant effect on production.	1
	Possible:	10
	Maximum:	7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031SdLP.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Sd
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.10, D.1, D.3, D.4, D.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

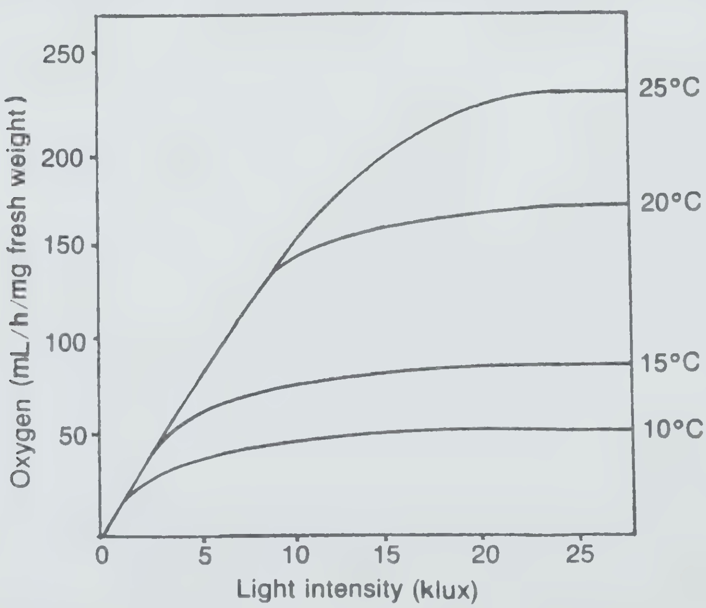
The student should be able to interpret graphs of data obtained from experiments involving photosynthesis.

Item

A. Examine Figure 3S.16, and explain the shapes of the curves shown.

B. Predict the results that would be obtained if the experiment were repeated at 30^oC, 40^oC, and 50^oC.

Rate of Photosynthesis as shown by the Release of Oxygen.



Response/Marking Scheme

A. At the four temperatures the curves show a common slope at low light intensities because light is then the limiting factor for photosynthesis. 3

From the common slope one can deduce that the enzymes involved in photosynthesis have a maximum efficiency under the limits of light and temperature. 2

As the light intensity increases, the curves separate, as 1

the rate of photosynthesis now varies with the temperature. 1

At higher temperatures, photosynthesis proceeds at a faster rate, and light is no longer the limiting factor. 2

Now the rate is controlled by enzymes, whose activity depends on the temperature. 2

All curves end in plateaus, when the limiting factor ceases to be light or temperature, and is the amount of carbon dioxide available. 2

Possible: 12

Maximum: 10

B. The trend of the graph would likely continue for the curve at 30^oC, reaching a plateau higher than that for 25^oC. 1

The trend might also continue for the 40^oC curve. 1

Between 40^oC and 50^oC the enzymes involved would be denatured, and would cease to function. 2

The result might be no oxygen evolution at all. 1

Possible: 5

Maximum: 4

Total: 14

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Conditions Affecting Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031SdSA.01
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3S.17.

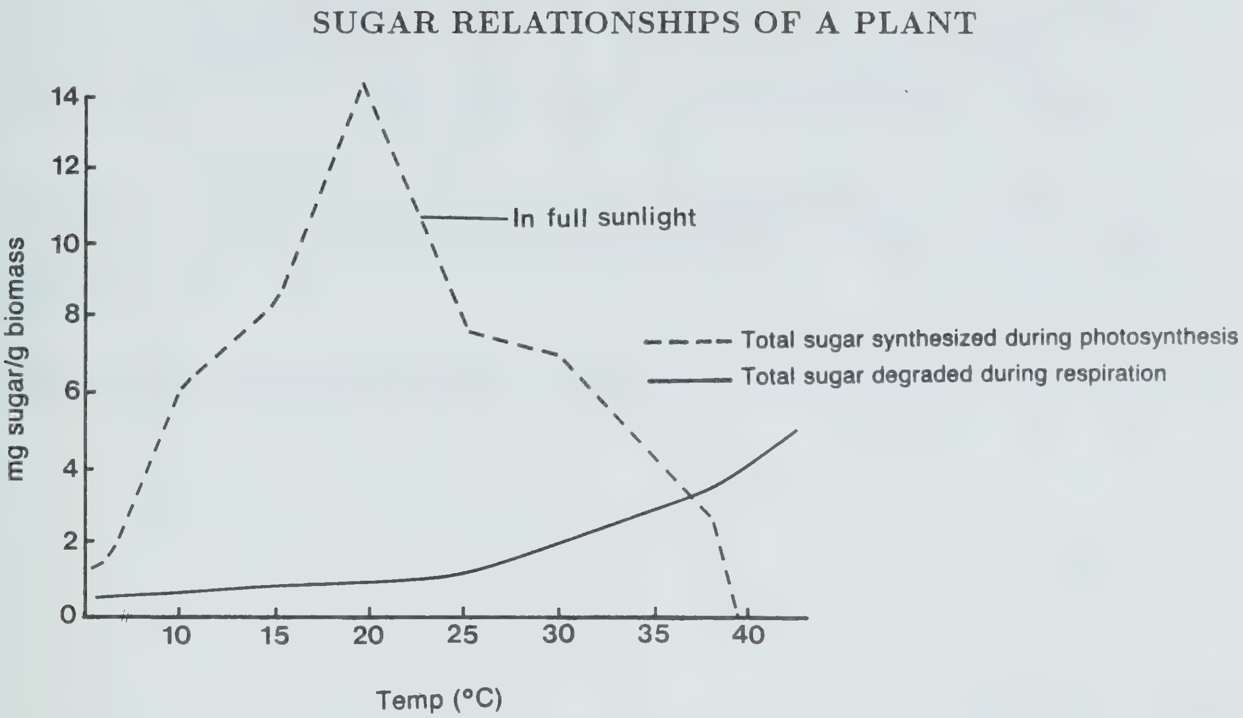


Figure 3S.17 shows the sugar relationships of a plant under different conditions of light. If a plant was placed in light of the intensity of full sunlight at 25^oC for 48 hours, what would be the net effect on the sugar content of the plant? Explain your answer.

Response/Marking Scheme

The plant will increase in sugar content	1
because of the fact that it is synthesizing sugar	2
at a faster rate than it is degrading sugar for metabolic processes.	1
Possible:	4
Maximum:	4

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Conditions Affecting Photosynthesis.
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031SdSA.02
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: photosynthesis graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3S.18.

SUGAR RELATIONSHIPS OF A PLANT IN THE SHADE

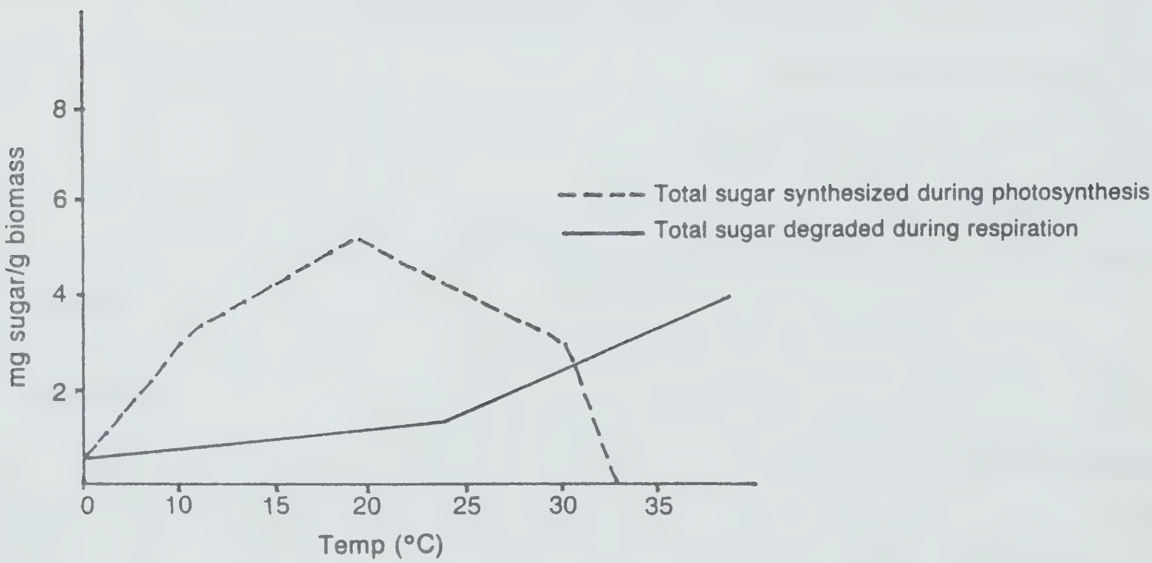


Figure 3S.18 shows the sugar relationship of a plant. Describe the net effect on the sugar content of the plant in the shade at 30^oC for 48 hours.

Response/Marking Scheme

The plant placed in shade at 30^oC for 48 hours should remain constant in mass 1

because it is synthesizing sugar at a rate equal to the rate at which its metabolic processes are utilizing it. 1

Possible: 2

Maximum: 2

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031SdSA.03
GUIDELINE OBJECTIVE CODE: 31Sd
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10,A.11. D.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: chlorophyll absorption spectrum graphical analysis

Guideline Objective

Students will have the opportunity to develop skill in interpreting data obtained from experiments on photosynthesis.

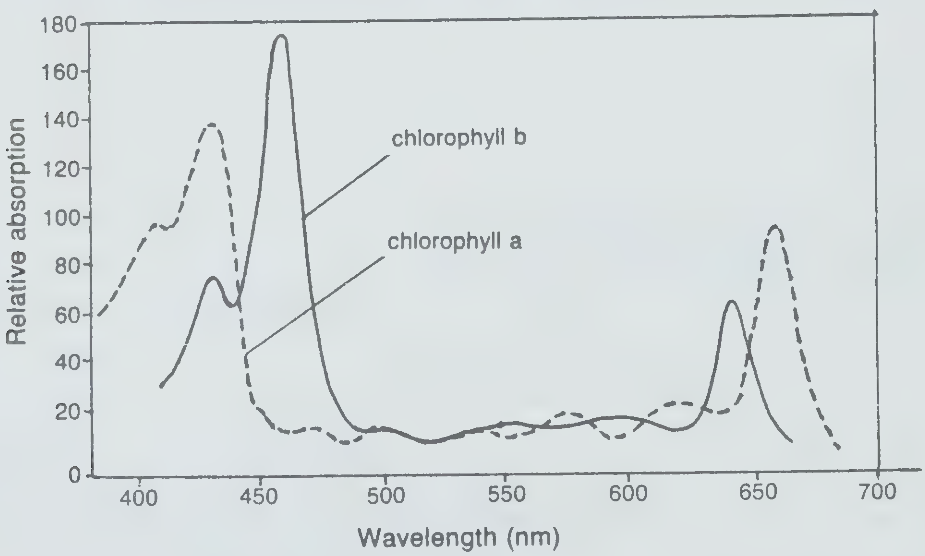
Item Focus

The student should be able to relate the absorption spectrum of chlorophyll to its role in photosynthesis.

Item

Refer to figure 3S.19.

THE ABSORPTION SPECTRA OF TWO TYPES OF CHLOROPHYLL



Explain the significance of Figure 3S.19 and its relationship to photosynthesis.

Response/Marking Scheme

Figure 3S.19 is the absorption spectrum of	1
chlorophylls a and b, two photosynthetic molecules or light trapping pigments.	2
The graph represents the absorption of energy at the varying wavelengths of light.	1
This energy can then be utilized for the process of photosynthesis.	1
Possible:	5
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3.
TOPIC: Plant Structures/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: plasmodesmata cell wall

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to identify the location of plasmodesmata in plant cells.

Item

In a plant cell, with which of the following structures would plasmodesmata be most closely associated?

☐ A. cell wall

☐ B. nucleus

☐ C. spindle fibres

☐ D. nucleolus

☐ E. chromosomes

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: transpiration pull

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to identify the factors involved in raising water from the roots to the leaves.

Item

Which of the following forces are involved in creating transpiration pull, the major factor in moving water from the roots of a plant to the leaves?

I capillarity.
II atmospheric pressure.
III adhesion of molecules.
IV molecular cohesion.
V root pressure.

Select your answer from the following:

☐ A. I, II, III only.

☐ B. I, III, V only.

☐ C. II, IV, V only.

☐ D. I, III, IV only.

☐ E. I, II, III, IV, and V.

Response/Marking Scheme

Correct response: D

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Translocation	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phloem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to identify a definition for translocation.

Item

The movement of dissolved materials, mostly sugars, throughout the phloem vessels in a plant is called

☐ A. diffusion.

☐ B. assimilation.

☐ C. transpiration.

☐ D. absorption.

☐ E. translocation.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaMC.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.9
	DIFFICULTY LEVEL: L
TOPIC: Transpiration	TIME ALLOCATION:
CURRICULAR EMPHASIS: Solid Foundations	

KEYWORDS: xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to identify the energy source necessary for water movement in plants by transpiration

Item

The energy which causes the rise of water in xylem by means of transpiration pull comes from the

☐ A. hydrogen bonds of the water molecules.

☐ B. adhesion.

☐ C. sugar dissolved in the sap.

☐ D. radiant energy of the sun.

☐ E. cohesion of water molecules.

Response/Marking Scheme

Correct response: D

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.9
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: tensile strength cohesion xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to identify factors which affect the movement of water in a tree.

Item

Which of the following factors affect the tensile strength of the columns of water caused by the cohesive forces between the water molecules in the xylem vessels of a stem?

I temperature
II the lignification of the vessels
III the diameter of the vessels
IV the height of the stem
V the humidity of the air
VI the continuity of the columns of water

Select your response from:

- ☐ A. I, II, and V only
- ☐ B. II, IV, and V only
- ☐ C. III, V, and VI only
- ☐ D. IV, V, and VI only
- ☐ E. I, III, and VI only

Response/Marking Scheme

Correct response: E

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Leaf structure
CURRICULAR EMPHASIS: Communication

INSTRUMENT CODE: B031KaDL.01
GUIDELINE OBJECTIVE CODE: 31Ka
INSTRUMENT TYPE: DL
KLOPFER: A.1, A.2, A.3, A.11
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: leaf cross-section

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to draw and label the arrangement of tissues in the cross-section of a mesophytic leaf.

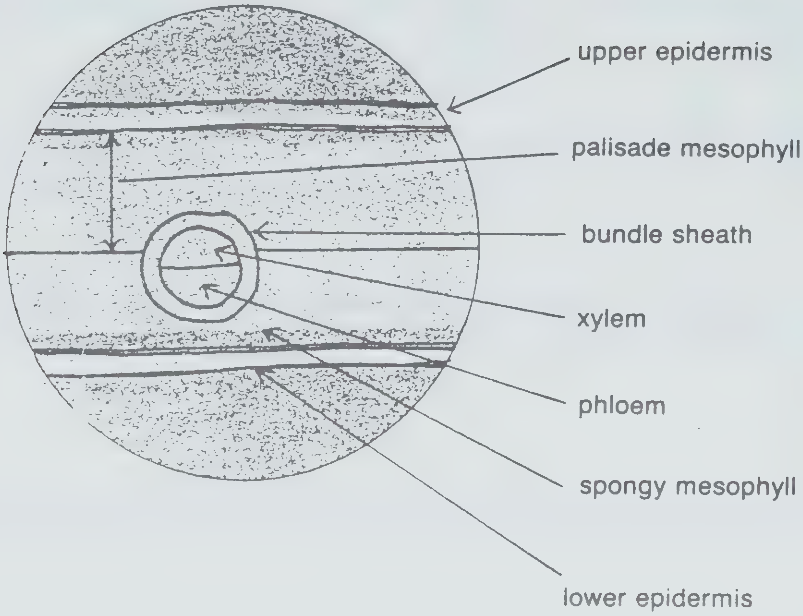
Item

A. Draw and label a "map" of the arrangement of tissues in a typical mesophytic leaf as you would see them if you were to examine a cross-section of the leaf under the low power of a microscope.

B. Why is the cuticle NOT considered a tissue?

Response/Marking Scheme

A.



labels: 7
drawing: 2

B. The cuticle is not made of cells.
It is a product exuded by the epidermal cells. 2

Possible: 11

Maximum: 9

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaEE.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: EE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5.
TOPIC: Transport of Materials	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: translocation leaf pull capillarity xylem phloem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student will describe the basic structure of transport vessels, and account for the transport of raw materials to the sites of photosynthesis.

Item

The Douglas fir and the giant sequoia are trees that can grow to heights of 100 m.

Explain two theories that are used to account for the rise of water to such heights.

Response/Marking Scheme

The processes involved in moving the water up to the leaves are capillarity, root pressure, and transpiration pull. (any 2) 2

Capillarity in the narrow xylem vessels is caused by the adhesive and cohesive properties of water molecules. 2

The water molecules adhere to polar substances found in the walls of the vessels; this causes an upward movement of water near the walls. 1

This, in turn, pulls the water in the centre of the vessel up, due to cohesive forces between water molecules; because of the small diameter of the vessels, there is a very large area of water in contact with the vessel walls in relation to the mass of water to be pulled up. 1

In a plant, capillarity could only raise water to an approximate height of 2 m. 1

Root pressure is the force by which water is pushed up the xylem vessels from the roots. 1

The accumulation of ions in the root cells by active transport from the soil solution lowers the water potential of the sap in the xylem. 1

Root pressure can only raise water about 1 m in the xylem. 1

Transpiration pull is the major force in moving water from the roots to the leaves. 1

It is caused by the cohesive properties of water molecules, together with the build up of tension in the xylem vessels. 1

As water molecules evaporate from the mesophyll cells, the water potential of the cells drops, and more water moves into the cells by osmosis from the xylem vessels. 1

This in turn pulls up more water, molecule by molecule, through the vessels. 1

A continuous column of water, from roots to leaves, is essential for transpiration pull to succeed. Due to cohesive forces, this column has considerable tensile strength. 1

The adhesive forces between the water molecules and the vessel walls works against transpiration pull, increasing the force required to raise water; however these forces prevent the formation of air bubbles that would break the water column, interrupting cohesion. 1

Possible: 16

Maximum: 12

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaEE.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: EE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Plant Transport Vessels	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: bark wood phloem xylem cambium

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe the structures and functions of plant transport tissues.

Item

Refer to Figure 3K.1 to answer this question.

CROSS SECTION OF THE STEM OF A CHERRY TREE

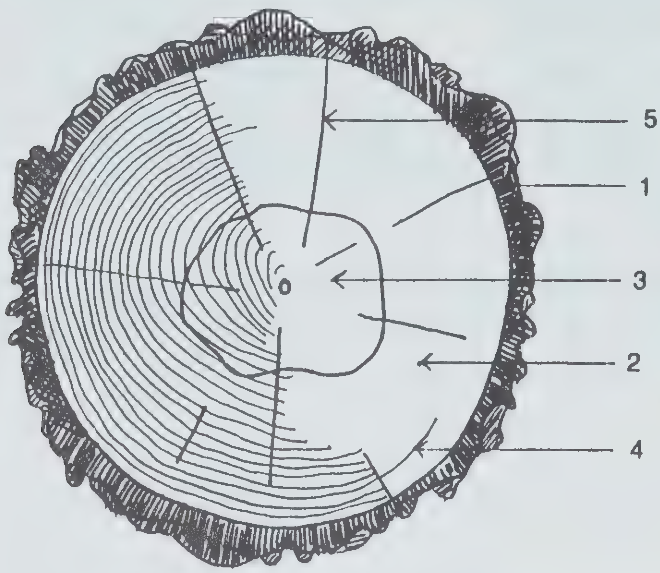


Figure 3K.1 represents a cross section of the stem of a felled cherry tree.

A. Make a list, in order, from the outside of the trunk to the centre, of the tissues present in the bark and wood.

B. Using a simple chart format, briefly state the function of each of the tissues.

Response/Marking Scheme

A. The tissues in order from outside to centre of cross-section are:

cork, cork cambium, phloem (sieve tubes, companion cells), phloem parenchyma, vascular cambium, xylem (tracheids, fibres, vessels) and xylem parenchyma 10

B.

Tissue	Function
cork	dead, suberized cells, almost impermeable to water and gases. Prevents splitting. Protects against loss of water, weather, disease and slight mechanical injury. 2
cork cambium	meristematic cells which divide to form a new layer of cork each spring. 2
phloem - sieve tubes	translocate manufactured foods throughout the plant. 2
companion cells	maintain metabolism of sieve tubes. 2
phloem parenchyma	irregular groups of undifferentiated cells which store water and food. 2
vascular cambium	meristematic cells which divide to form phloem on the outside and xylem on the inside. 2
xylem (wood) tracheids, fibres and vessels	support trunk and transport water and mineral salts 2
xylem parenchyma	(as for phloem parenchyma) 1

Possible: 25

Maximum: 20

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaEE.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: EE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: cork cork cambium phelloderm cortex phloem vascular cambium xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student will will describe the basic structure of transport vessels, emphasizing that cells are living and are interconnected across their walls by extensions of the cytoplasm (plasmodesmata).

Item

The following plant tissues are found in a woody stem:

cortex, vascular cambium, cork, xylem, phelloderm, phloem, and cork cambium

Arrange these tissues in the order in which they occur in the stem, from the outside of the stem to the centre. For each tissue, give a concise account of the structure and function.

Response/Marking Scheme

Correct order is as follows:

cork, cork cambium, phelloderm, cortex, phloem, vascular cambium, and xylem

correct sequence 2

Structure and Functions:

<u>cork</u>

- flat, thin-walled, dead cells 1
- suberized walls, almost impermeable to water and gases. 1
- growth of new cork each spring prevents splitting of stem, protects against loss of water, weather, disease, and slight mechanical injury. 2

<u>cork cambium</u>

- flat, thin-walled, meristematic cells 1
- divide to form cork on outside and phelloderm on inside 1

<u>phelloderm</u>

- parenchyma-like cells, undifferentiated, thin-walled, living, isodiametric 1
- storage of food and water, may contain chloroplasts, potential for differentiation 1

<u>cortex</u>

- complex tissue, may contain parenchyma, collenchyma, sclerenchyma 1
- parenchyma (see above)

- collenchyma, living, elongated cells, thickened at corners, walls of pectin and cellulose, may contain chloroplasts 1
- strengthening tissue 1
- sclerenchyma, dead sclerids and fibres 1
- thick, strong, lignified cells 1
- support and protection 1

<u>phloem</u>

- elongated sieve tubes 1

- each sieve tube contains vertical rows of sieve tube members. 1
- each sieve tube member consists of a sieve tube element and a companion cell 1
- mature sieve tube element is living, no nucleus, thinner layer of cytoplasm, very small mitochondria, organelles lose members, large central vacuole containing fine threads of P-protein 3
- sieve elements separated by perforated end walls, sieve plates 1
- phloem translocates manufactured food substances from the leaves to other parts of plant 1
- companion cell - living, dense, granular contents, retains nucleus and organelles 1
- supports metabolism of sieve tube element 1

<u>vascular cambium</u>

- thin-walled, brick-like cells 1
- divide to form new phloem and xylem 1

<u>xylem</u>

- tracheids: dead, single, elongated cells, pointed at ends, lignified, pitted 1
- vessel: when mature, long, dead, narrow tubes, thickened, lignified walls, 1

lignin laid down in different patterns, annular, spiral, scalariform, and reticulate 1

- some vessels have simple or bordered pits 1
- supports stem and transports water and mineral salts 1

Possible: 31

Maximum: 25

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaEE.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: EE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: adhesion cohesion capillarity osmosis root pressure transpiration pull xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to trace the pathway taken by water from the soil to the palisade cells of a leaf, and explain the forces involved in its movement.

Item

Trace in detail the pathway water takes from the soil to the palisade cells of a leaf. Explain the forces involved in the movement of water along this pathway.

Response/Marking Scheme

1. Water from the soil enters the root hairs of a root by osmosis. 1

   Osmosis is the diffusion of water molecules through a selectively permeable membrane from a solution with fewer solute particles (more water molecules per unit volume) into a solution with more solute particles (fewer water molecules per unit volume). 2

2. From the root hairs, water flows along the surfaces of cells or through the cell walls to xylem in the stele. 1

   Some water moves from cell to cell across the cortex of the root by osmosis through selectively permeable cell membranes, and through the plasmodesmata. 1

3. Casparian strips, an impermeable band in the walls of the endodermal cells block the movement of water through the cell walls; thus water must move through the cell membranes of the endodermis. 1

4. Water enters the xylem vessels of the root, and flows up the continuous pathway of xylem vessels from root to stem to leaf petiole, to midrib to fibrovascular bundles (veins) to the mesophyll cells in the leaf. 4

5. The processes involved in moving the water up to the leaves are capillarity, root pressure, and transpiration pull. 3

   Capillarity in the narrow xylem vessels is caused by the adhesive and cohesive properties of water molecules. 2

   The water molecules adhere to polar substances found in the walls of the vessels; this causes an upward movement of water near the walls. 1

   This, in turn, pulls the water in the centre of the vessel up, due to cohesive forces between water molecules; because of the small diameter of the vessels, there is a very large area of water in contact with the vessel walls in relation to the mass of water to be pulled up. 1

   In a plant, capillarity could only raise water to an approximate height of 2 m. 1

6. Root pressure contributes to the force by which water is pushed up the xylem vessels from the roots. 1

   The accumulation of ions in the root cells by active transport from the soil solution lowers the water potential of the sap in the xylem. 1

   Root pressure alone could only raise water about 1 m in the xylem. 1

7. Transpiration pull is the major force in moving water from the roots to the leaves. 1

It is caused by the cohesive properties of water molecules, together with the build up of tension in the xylem vessels. 1

As water molecules evaporate from the mesophyll cells, the water potential of the cells drops, and more water moves into the cells by osmosis from the xylem vessels. 1

This in turn pulls up more water, molecule by molecule, through the vessels. 1

A continuous column of water, from roots to leaves, is essential for transpiration pull to succeed. Due to cohesive forces, this column has considerable tensile strength. 1

The adhesive forces between the water molecules and the vessel walls works against transpiration pull, increasing the force required to raise water; however these forces prevent the formation of air bubbles that would break the water column, interrupting cohesion. 1

8. The energy for transpiration pull comes from the sun, which causes the evaporation of water from the leaves. 1

Possible: 28

Maximum: 20

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaEE.05R
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: EE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.8, A.9
TOPIC: Phloem Structure/Function	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: translocation pressure-flow theory

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe the structure and the function of phloem tissue in a flowering plant.

Item

Describe the structure and functions of the four types of cells found in phloem tissue in a flowering plant. Include in your answer,

A. a description of the differentiation of sieve tubes and companion cells from cambium cells.

B. a brief description of the structure and function of the phloem parenchyma and the phloem fibre cells.

C. the details of the materials translocated in the phloem and summarize the pressure-flow mechanism (model) which explains their movements.

Response/Marking Scheme

A. Sieve element and companion cell are differentiated from the products of a longitudinal, unequal, division of a cambium cell 1

Sieve element

- elongated cell - nucleus gradually disintegrates. 1
- plastids lose most of their internal membranes 1
- mitochondria are smaller than normal 1
- cytoplasm is much reduced, forming thin, peripheral layer 1
- central part of element contains meshwork of tangled protein fibres (P protein)
  referred to as protein slime 1
- end walls of sieve elements become perforated to form sieve plates 1
- strands of cytoplasm continuous through holes in sieve plates 1
- sieve areas also occur in side walls 1
- vertical row of several sieve elements constitues a sieve tube 1
- each sieve element has a companion cell associated with it 1

Companion cell

- has normal protoplast with dense, granular cytoplasm and a nucleus 1
- full complement of organelles, including many mitochondria 1
- large numbers of plasmodesmata in walls between companion cells and sieve elements 1
- companion cells may exert some control over metabolism of sieve elements 1

B. Phloem parenchyma

- undifferentiated cells between phloem elements 1
- large vacuoles and thin cell walls 1
- may function as storage cells and for lateral transport of solutes and water 2

Phloem fibres

- thick-walled cells, support phloem tissue 2

C.

- Sieve tubes translocate a concentrated solution of organic compounds, mostly sucrose plus some amino acids and other organic compounds 2
- the pressure-flow mechanism of phloem transport suggests that sucrose enters
  the sieve tubes at leaf sources and is removed at sinks (e.g., roots, fruits, growing points) 1
- both the entry and removal of sucrose form sieve tubes requires energy 1
- at sources, ATP provides energy to pump H^+ out of the sieve elements 1
- H^+ gradient establishes an electro-chemical difference across the plasma membranes 1
- this energy is used by a carrier molecule to transport the H^+'s back into the sieve elements, together with the sucrose 1
- some minerals may move through the plasmodesmata 1
- at sinks, the opposite happens; H^+'s are pumped into the sieve elements, then carrier molecule plus H^+ plus sucrose, moves out 2
- the movement of sap inside the sieve tubes is explained by osmotic pressure differences 1
- there is a high osmotic concentration at the sources, as the sap is pushed towards the sinks, the concentration of sucrose decreases the osmotic pressure, establishing a concentration gradient from the source to the sink. 3
- the pressure-flow mechanism of phloem transport leaves a number of questions
  unanswered. Other theories exist to explain the same phenomenon. The topic is still under active investigation. 1

Possible: 35

Maximum: 25

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Plant Transport Vessels
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KaEE.06
GUIDELINE OBJECTIVE CODE: 31Ka
INSTRUMENT TYPE: EE
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: phloem xylem cambium

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe the structures and functions of plant transport tissues.

Item

Refer to Figure 3K.2.

CROSS SECTION OF THE STEM OF A CHERRY TREE

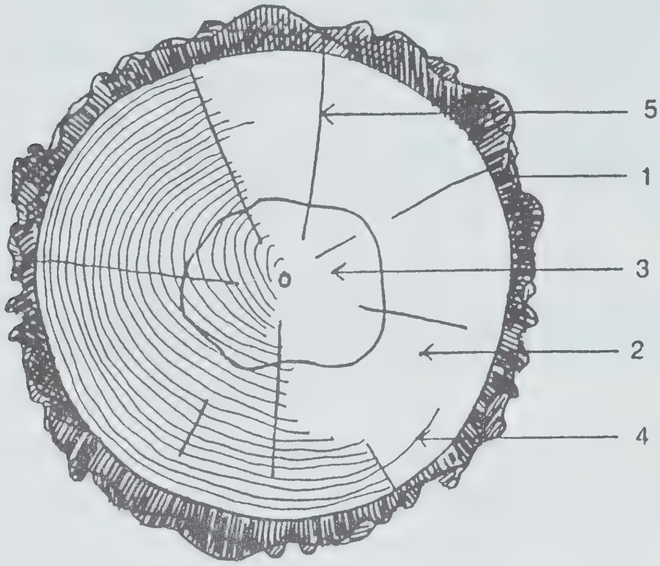


Figure 3K.2 represents a cross section of the stem of a felled cherry tree.

A. Explain the differences between the two kinds of wood shown on the figure (labelled '2' and '3')

B. What is labelled '4'? Describe its structure and state its function.

C. What is labelled '5'? Describe its structure and state its function.

Response/Marking Scheme

A. '2' is the softer lighter, younger sapwood - both supports and conducts water and mineral salts — 2

'3' is the harder, darker, compact, older, heartwood—supports (no conduction). — 2

B. '4' is an annual ring — 1

- xylem elements formed in the spring have large lumens and thin walls to carry the large volume of water and salts required for spring growth. — 1
- xylem elements formed in the summer have progressively smaller lumens and thicker walls — 1
  which would be followed by next spring's growth — 1
- the annual ring thus marks the boundary between the summer wood and the following spring wood. — 1
- space between 2 rings constitutes 1 year's growth — 1

C. '5' is a ray (medullary or vascular) — 1

- radial plates of elongated parenchyma cells — 1
  produced from vascular cambium — 1
- xylem rays on inside of cambium, phloem rays on outside, continuous radially. — 1
- irregular sized plates both radially and vertically — 1
  conduct materials radially in the trunk — 1
  and food to living tissues in the xylem and water and minerals to living tissues in bark — 1
- some rays may store food — 1

Possible: 18

Maximum: 15

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10
TOPIC: Transport of Materials	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: mineral mineral deficiency phloem xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to apply knowledge of plant transport to a new problem.

Item

For a long time, gardeners have known that mineral deficiencies of the soil manifest themselves as characteristic discolourations in the leaves of the plants growing in that soil. Some deficiencies first show themselves in young leaves, while others are first observed in older leaves. Use your knowledge of translocation in plants to account for these differences.

Response/Marking Scheme

Although all mineral ions come from soil, some are transported exclusively by xylem tissues.	1
Others are transported by xylem and phloem tissues.	1
If a mineral is carried only by the xylem, then its deficiency will first show up in leaves forming at the time the deficiency in the soil develops,	1
i.e. in the younger leaves.	1
Because xylem flow is unidirectional, from stem to leaf,	1
such minerals cannot be moved out of older leaves. If the mineral is transported by phloem, it can be removed from senescent leaves and carried to younger, developing leaves.	1
Thus, signs of deficiency are seen first in older leaves.	1
Maximum:	5
Possible:	7

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Raw Materials of Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KaER.02
GUIDELINE OBJECTIVE CODE: 31Ka
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, A.5.
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: translocation leaf pull capillarity xylem phloem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

Same as above.

Item

The Douglas fir and the giant sequoia are trees that can grow to heights of 100 m.

Explain how the theories of molecular cohesion and transpiration pull are used to account for the rise of water to such heights.

Response/Marking Scheme

Transpiration pull is the major force in moving water from the roots to the leaves. 1

It is caused by the cohesive properties of water molecules, together with the build up of tension in the xylem vessels. 1

As water molecules evaporate from the mesophyll cells, 1

the water potential of the cells drops, and more water 1

moves into the cells by osmosis from the xylem vessels. 1

This in turn pulls up more water, molecule by molecule, through the vessels. 1

A continuous column of water, from roots to leaves, is essential for transpiration pull to succeed. Due to the 1

force of molecular cohesion, this column has considerable tensile strength. 1

The adhesive forces between the water molecules and the vessel walls works against transpiration pull, increasing 1

the force required to raise water; however these forces prevent the formation of air bubbles that would break the water column, interrupting cohesion. 1

Possible: 10

Maximum: 7

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: osmosis transpiration pull

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe and explain the rise of water in a woody tree.

Item

Some large trees give off as much as 500 L of water a day.

A. Name and explain three forces involved in the rise of water in a stem.

B. What is the adaptive advantage to a plant to move so much water?

Response/Marking Scheme

A. Accept any three forces @ 2 marks each:

Root pressure is created by the force of osmosis across the cells of a root, supplying water to the xylem. 2

Molecular cohesion, the attraction of adjacent water molecules for one another, creates a column of water that holds together without gaps or air spaces as it rises in the xylem. 2

Molecular adhesion, the attraction of the cellulose walls of the xylem for water molecules, helps to pull water up the xylem by capillarity. 2

Transpiration pull originates in the mesophyll cells of the leaves by the evaporation of water from the cell walls into the leaf spaces. This force continues to draw water out of the tops of the xylem system. 2

B. Large quantities of water are moved in order to maintain the forces that lift water, so that a steady supply of water will be available. 2

Also, since mineral ions are in very low concentration in the soil solution, the movement of much water helps to concentrate the mineral ions in the tissues. 1

Transpiration serves the function of cooling the plant in hot environments. 1

Possible: 10

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaER.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Transport of Materials	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: translocation leaf pull capillarity xylem phloem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student will describe the basic structure of transport vessels, and account for the transport of raw materials to the sites of photosynthesis.

Item

Describe the tissues of a tree trunk that are involved in the process of translocation.

Response/Marking Scheme

Translocation is the movement of organic substances through a plant, primarily the sugars and amino acids manufactured during photosynthesis.	2
The tissues involved are phloem elements, the sieve tubes and companion cells.	2
Sieve tube elements are elongated cells with perforated end walls (sieve plates), where the cytoplasm of one cell extends through the holes into the next cell.	3
When mature, sieve tube elements lack a nucleus and have very few mitochondria. They depend on adjacent companion cells for energy and synthesis.	2
Companion cells have enlarged nuclei and compact cytoplasm, and are connected to the sieve tube elements by plasmodesmata, cytoplasmic extensions through pores in their mutual cell walls.	2
Possible:	11
Maximum:	8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.8
TOPIC: Plant Ion Transport	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ion root hair xylem plasma membrane plasmodesmata

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe the movement of ions in a plant.

Item

When ions move across a root from root hairs to xylem, they can travel by one of three possible pathways:

a. along the cell wall pathway
b. through the cytoplasm pathway
c. from cell vacuole to cell vacuole

Assume that the ions are moving in the cytoplasm pathway. Describe the ways in which the ions could move from cell to cell. Give details of the cell structures involved.

Response/Marking Scheme

Ions could diffuse or be actively transported from cell to cell through the plasma membranes,	2
diffusing through the cell walls and middle lamellae.	1
The plasma membrane consists of groups of protein molecules embedded in a fluid phospholipid bilayer.	2
The cell wall consists of cellulose molecules laid down in layers of microfibrils	1
The middle lamella is a pectin-rich common partition between adjacent cells.	1
The ions could also move through the plasmodesmata.	1
Large numbers of plasmodesmata provide cytoplasmic connections across the cell walls of adjacent cells.	1
Tubular structures lined by plasma membranes have a central desmotubule surrounded by cytoplasm.	1
The desmotubule connects the endoplasmic reticula of adjacent cells.	1
Ions may move through either the cytoplasm or the desmotubule, or both.	1
Possible:	12
Maximum:	10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.6, A.10.
TOPIC: Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: sieve tube companion cell vessel element

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to discuss the relationship between the structure of cells and vessels involved in plant transport and their functioning.

Item

Discuss the structure and functioning of each of the following in relation to the transport of materials through a plant:

A. sieve tubes,
B. companion cells,
C. xylem elements.

Response/Marking Scheme

A. Sieve tubes are part of the phloem tissue. 1
They form long narrow columns, and at the end walls 1
where two cells meet there are perforations (sieve 2
plates) that permit the cytoplasm to stream from one 1
cell to the next. The sieve tube elements lack nuclei, endoplasmic reticulum, and have very few mitochondria. 2
Sieve tubes are specialized for rapid translocation of plant sap, containing sugars 2
and amino acids. 1

Possible: 10

Maximum: 7

B. Companion cells are found in the phloem, in close association with the sieve tubes. 1
They have prominent nuclei. 1
Since the death of a companion cell results in the loss of function of its related sieve tube, companion cells are thought to control the sieve tube elements. 2

Possible: 4

Maximum: 3

C. Xylem elements are very large, long, and devoid of cell contents. 3
Their walls are lignified, preventing loss of water. 1
Between adjacent vessels, the side walls may be perforated to facilitate transfer of water. 1
Vessels carry water and dissolved minerals from the roots through the plant. 2

Possible: 7

Maximum: 5

Total: 15

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.9, D.3
TOPIC: Transport of Materials	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: cohesion/tension theory xylem

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to, given a set observations, explain water movement in plants in terms of the cohesion/tension theory of water movement.

Item

A plant physiologist, working with grape vines, made cross cuts in the stems at different heights, so that all the large xylem vessels were cut at different parts of the stem. He observed that the rate of water uptake and transpiration continued at a normal rate and the leaves did not wilt. Discuss these observations and give possible explanations in terms of the tissue involved and the cohesion/tension theory of water movement in plants.

Response/Marking Scheme

- no loss of water supply to leaves	1
- although continuous vertical flow of water in the xylem tracheids and vessels was interrupted by the saw cuts	2
- results suggest water must have moved laterally through the non-lignified parts of the xylem tissue.	2
- e.g., simple and bordered pits	1
- continued upward flow in parts of stem not blocked by saw cuts	1
- illustrates the significance of the lateral continuity of the water molecules in a stem, since this continuity is essential for the cohesion/tension theory of water movement in xylem.	2
Possible:	9
Maximum:	6

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.7, H.1, I.4
TOPIC: Transport of Materials	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Practical Application	TIME ALLOCATION:

KEYWORDS: sap translocation

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to explain the movement of sap in a deciduous tree, using a knowledge of plant transport.

Item

Many of you have enjoyed the traditional 'tapping' of maple trees in early spring to obtain the fluid which will eventually become maple syrup.

A. Which tissue of the trunk is being tapped?

B. In which direction is most of the fluid flowing?

C. What is causing the movement of the fluid in the trunk?

D. In what form is the carbohydrate stored for winter? Into what form is it converted in early spring?

E. Why was the stored material converted to sugar in the spring?

Response/Marking Scheme

A.	xylem	1
B.	up (recent knowledge suggests that the flow may also be downward)	1
C.	mostly root pressure, some capillary attraction (no leaves yet for transpiration pull)	2
	(expansion of fluid because of warm days, and lateral transport may assist)	
D.	In late summer and early fall, starch was stored in the xylem because starch is not active osmotically.	2
E.	Starch is converted to sucrose and other sugars to be soluble forms for translocation.	2
	Possible:	8
	Maximum:	6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, D.3, I.3
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: girdling bark wood

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to interpret data as it relates to water transport in trees.

Item

Some of the earliest experiments in plant physiology (Malpighi, 1675; Hales, 1727) involved the "girdling" of trees, (the removal of a complete ring of bark from the trunk). Consider the following observations on the experimental trees sometime after they were girdled.

A. There was no immediate effect on shoot growth or transpiration.

B. The bark above the girdle remained healthy, swelled, and exuded a sweet fluid.

C. The bark below the girdle dried up and died.

D. An entire year's growth was laid down above the girdle, not below it.

E. Eventually, sometimes after many months, the girdled trees wilted and died.

Interpret each of the five observations. What conclusions can be drawn from them regarding the transport of materials in a tree?

Response/Marking Scheme

A.	The shoot was not deprived of materials required for growth.	1
	There was no restriction in the supply of water.	1
	Water and dissolved mineral salts travel in the wood (xylem), upwards from roots to shoot.	1
B. and D.	Bark above girdle continued to grow.	1
	Manufactured substances (sugars) in exuded fluid.	1
C.	Bark below girdle deprived of essential materials.	1
	Manufactured substances (food) carried by tissues in the bark, down from the leaves to the roots.	1
E.	After the roots had used up their stored food, they would wither and die,	1
	since no more food can reach them past the girdle.	1
	When the roots died, the shoot soon wilted and died through lack of water and minerals.	1
	Possible:	10
	Maximum:	9

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KaSA.07
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ka
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.9
TOPIC: Plant Ion Transport	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ion endodermis plasmodesmata

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to describe ion transport in plants.

Item

Describe the three possible pathways ions may follow in moving across a root from a root hair to a xylem element. Mention the specialized structure of the endodermal cells and how this affects the ion transport.

Response/Marking Scheme

Possible ion pathways are as follows:

1. Ions could travel along (through) the cell walls of the epidermal and cortical cells as far as the endodermis. 1

   This path consists of the water-filled interconnected spaces in the non-living materials of the cells. 1

   On reaching the endodermis, the ions must pass through the cells. 1

   They cannot move around cells in walls because of the impermeable cell-like Casparian strip present in the radial and transverse walls of the endodermal cells. 2

   The inside and outside tangential walls which lie parallel to the outside of the root are not suberized, allowing the ions to move in and out of the endodermal cells. 1

   The ions may then return to the apoplast (by diffusion or active transport) and continue to the xylem. 1
2. The ions could travel by way of the cytoplasmic pathway, from cell to cell, 1

   either by passing through successive plasma membranes from cell to cell, 1

   or by passing through intercellular cytoplasmic connections called plasmodesmata 1
3. Ions could also travel from cell vacuole to cell vacuole across the root by osmosis. 2

   This is much slower and the ions would have to pass through the cell wall, plasma membrane, cytoplasm, vacuolar membrane going into or going out of each cell. 1

Possible: 12

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology

LEVEL: OAC

UNIT NUMBER: 03

UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

TOPIC: Plant Essential Elements

CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KaSA.08

GUIDELINE OBJECTIVE CODE: 31Ka

INSTRUMENT TYPE: SA

KLOPFER: A.1, A.2, A.6

DIFFICULTY LEVEL: L

TIME ALLOCATION:

KEYWORDS: essential elements

Guideline Objective

Students will be expected to describe how materials are transported throughout plants in phloem and xylem tissue and also describe one model that accounts for the behaviour of water in these tissues.

Item Focus

The student should be able to list the essential elements of plants and state their functions.

Item

Complete the missing sections(*) of the following table:

Element	Form available to plants	A metabolic role in plant
sulphur	*	synthesis of amino acids (cysteine, methionine), coenzyme A, cytochromes and fatty acids
*	HPO_4^{2-} $H_2PO_4^-$	*
magnesium	*	*
*	Ca^{2+}	storage of harmful oxalates in central vacuole; associated with pectin; helps cement cells together; affects selective permeability of membranes
*	*	important in stomatal movements; activates many enzymes; aids translocation; maintains turgor; primary charge balancing cation in movement of anions
nitrogen	*	essential for synthesis of amino acids, nucleic acids, enzymes, coenzymes, and chlorophyll

Response/Marking Scheme

Element	Form	Metabolic role in plants (any use in each line)
	$*SO_4^{2-}$	1
*phosphorus		*phosphorylation during respiration synthesis of ATP, nucleic acids, some proteins, coenzymes, membrane phospho lipids, buffers; role in photosynthesis 2
	$* Mg^{2+}$	*essential for synthesis and activity of all chlorophyll molecules; promotes enzyme activity; essential for protein synthesis 2
*calcium		1
*potassium	$* K^+$	2
	$*NO_3^-$, NH_4^+	1

Possible: 9

Maximum: 9

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chloroplast

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the location of photosynthetic cells in leaves.

Item

In the leaves of most plants, chloroplasts are located in cells of

☐ A. the palisade mesophyll tissue only.

☐ B. the palisade and spongy mesophyll tissue only.

☐ C. the upper epidermis and the palisade mesophyll tissues only.

☐ D. the upper epidermis, palisade and spongy mesophyll tissue only.

☐ E. the palisade and spongy mesophyll tissue, and the guard cells of upper and lower epidermal tissue.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Chloroplast Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stroma thylakoid lamella grana

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

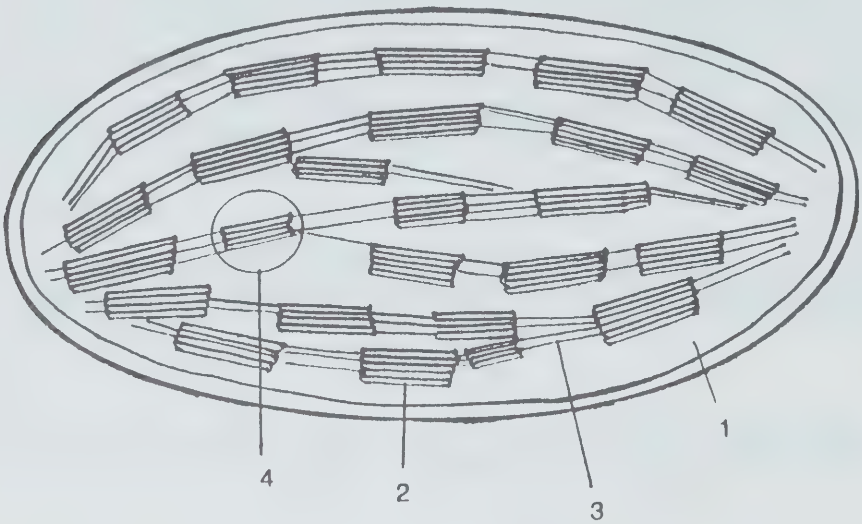
Item Focus

The student should be able to distinguish between grana and stroma.

Item

Refer to Figure 3K.3.

STRUCTURE OF A CHLOROPLAST



Numbering from 1 to 4, in correct order, the parts of the chloroplast labelled in Figure 3K.3 are as follows:

☐ A. stroma, thylakoid, lamella, granum

☐ B. thylakoid, stroma, granum, lamella

☐ C. stroma, lamella, thylakoid, granum

☐ D. granum, thylakoid, stroma, lamella

☐ E. lamella, granum, stroma, thylakoid

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Raw Materials of Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: carbon dioxide

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the source of carbon dioxide used in photosynthesis.

Item

Terrestrial plants obtain the carbon dioxide they require for photosynthesis mostly from the

☐ A. soil water, by diffusion in solution.

☐ B. soil atmosphere, by diffusion through air.

☐ C. atmosphere, by diffusion.

☐ D. carbonates in the soil.

☐ E. breakdown of stored starch.

Response/Marking Scheme

Correct response: C

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Transpiration	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to recognize a definition for transpiration.

Item

The process by which water vapour is lost from the exposed parts of plants is called

- [ ] A. perspiration.
- [ ] B. transcription.
- [ ] C. respiration.
- [ ] D. transpiration.
- [ ] E. guttation.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Operation of Stomata	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the factors that influence the opening and closing of stomata.

Item

Which of the following factors influence the opening and closing of the stomata?

I humidity
II the turgidity of the guard cells
III light intensity
IV soil moisture
V air temperature

Choose your answer from the following:

☐ A. I, III, and V only

☐ B. I and II only

☐ C. I, II, and V only

☐ D. I, II, III, and V only

☐ E. I, II, III, IV, and V

Response/Marking Scheme

Correct response: E

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMC.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Transpiration	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: xylem vessels

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

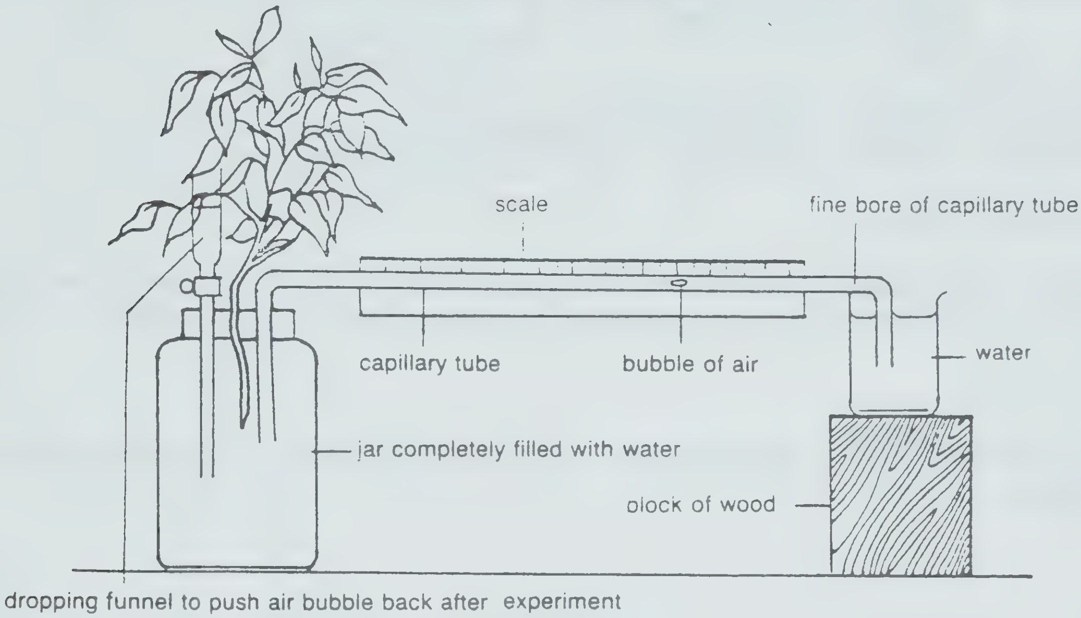
Item Focus

The student should be able to identify factors involved in the uptake of water and nutrients in an experimental set up.

Item

Refer to Figure 3K.4.

DEMONSTRATION OF PLANT TRANSPIRATION



Two virtually identical plants were set up in two identical apparati, shown in Figure 3K.4. The undersides of all of the leaves of Plant A were covered with petroleum jelly. The leaves of Plant B were left untouched. When left for a period of time, the bubble in the capillary tube travelled more quickly towards Plant B than it did towards Plant A. These data suggest that

- ☐ A. the plants were of different species.
- ☐ B. transpiration was taking place in both plants through the lower epidermis of the leaves only.
- ☐ C. transpiration was faster in Plant A than in Plant B.
- ☐ D. normally, transpiration would take place through both the upper and lower epidermis of the leaves.
- ☐ E. the water and minerals were taken up by the two plants, chiefly through xylem vessels.

Response/Marking Scheme

Correct response: D

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, D.1, D.3
TOPIC: Stomata	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: stomata potassium graphical analysis

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to interpret graphical data relating to the opening and closing of stomata.

Item

Refer to Figure 3K.5 to answer this question.

THE EFFECTS OF POTASSIUM ION CONCENTRATIONS ON STOMATAL OPENING

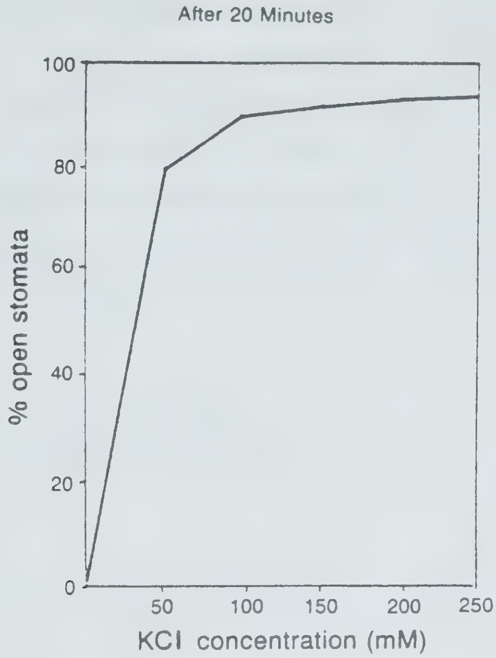


Figure 3K.5 illustrates the effects of varying concentrations of potassium ions on stomatal opening, using the leaves of *Trandescantia*, a common lab plant.

A. What interpretation can you draw from these data?

B. Can the conclusion to this activity be applied to the opening and closing of stomata on other plant species? Explain.

C. Suggest a reason why fewer stomata were open at a potassium chloride concentration of 250 mM than at 200 mM for the leaves which were examined after 20 min.

Response/Marking Scheme

A. At a concentration of 50 mM KCl, potassium chloride ions appear to cause approximately 80% of the stomata of *Tradescantia* leaves to open. 2

B. No. It would be necessary to perform this activity on the leaves of a variety of plants under a variety of controlled conditions to determine whether or not these results can be generalized. 2

C. Any reasonable hypothesis is acceptable. For example, students might suggest that a point has been reached where the concentration of potassium ions is now so high that the guard cells are being plasmolyzed. 2

Possible: 6

Maximum: 6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Guard Cells	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stoma

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to explain how the water content of guard cells determines the size of the stomatal opening between them.

Item

Explain how the water content of guard cells determines the size of the stomatal opening between them.

Response/Marking Scheme

As water enters guard cells, by osmosis, their turgor pressure increases, and they begin to swell. 2

Since the wall next to the stoma is much thicker than the wall away from the stoma, 1

it is less elastic. 1

Therefore, the guard cells become crescent-shaped 1

with the concave side next to the stoma 1

so the stoma becomes larger. 1

Conversely, if guard cells lose water, 1

they become flatter 1

and the stoma becomes smaller. 1

The movement of water into and out of guard cells appears to be controlled by the movement of potassium ions across 1

the cell membranes. When potassium ions enter the cells, water follows quickly, and the stoma opens. 1

Potassium ion flow appears to be related to the concentration of carbon dioxide. In light, photosynthesis removes carbon dioxide, potassium ions move in, and the stoma opens. 1

Possible: 13

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata guard cells

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to describe the structure and explain the functioning of guard cells.

Item

Explain why many species of plants keep their stomata open during the day, and close them at night.

Response/Marking Scheme

The change in the size of a stoma is caused by a change in the turgor of the guard cells. 1

The guard cells have a speciallized shape and structure, with a thin cell wall adjacent to the epidermal cells, and a very thick wall next to the stoma. 2

When the guard cells are turgid, the thin wall bulges into the epidermal cells, pulling the thick wall away from the stoma, opening it wider. 1

When the guard cells are flaccid, the thin walls straighten, allowing the thicker walls to spring back, closing the stoma. 1

The change in turgor of the guard cells is brought about by the active transport of potassium ions (K^+) from the adjacent epidermal cells into the guard cells, and the consequent osmosis of water from the epidermal cells into the guard cells. 2

Chloride ions may accompany the potassium ions, or hydrogen ions may move in the opposite direction to maintain electrical neutrality. 1

It has been suggested that the relationship between light intensity, movement of potassium ions, and the change in turgor leading to the opening of the stomata may be due to the change in pH caused by the using up of carbon dioxide when light strikes the chloroplasts in the guard cells. When the light intensity declines, the accumulation of carbon dioxide produces a decrease in pH. 2

Another possible mechanism is that photosynthesis in the guard cells produces glucose and the ATP required to maintain the active transport of the potassium ions. When photosynthesis stops, active transport can no longer be maintained, and the potassium ions diffuse back into the epidermal cells. The glucose affects the osmotic pressure of the guard cells, increasing cell turgor, and opening the stomata. 2

Possible: 12

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Structure/Function
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KbER.04
GUIDELINE OBJECTIVE CODE: 31Kb
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, A.6, A.10.
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: water deficit turgor wilting

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to explain the significance of water deficit to the physiology of a plant.

Item

To maintain cell turgor requires a high water content. Sugar in the cells helps to maintain the osmotic force needed to maintain turgor.

How does a water deficit affect the functioning of a plant?

Response/Marking Scheme

A water deficit stops photosynthesis, since water is a raw material for the process. If the deficit continues, sugar will not be available for maintaining turgor.	2
Loss of turgor causes the guard cells to close stomata,	2
reducing the exchange of gases and transpiration.	2
Water is the medium of transport of materials in solution through the plant; a water deficit reduces the flow of materials.	2
Wilting is the result of a severe water deficit, and if continued, may cause the death of the plant.	2
Possible:	10
Maximum:	7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Stomata	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata potassium ion

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to describe a current model which explains how stomata open.

Item

Describe the mechanism by which potassium ions function in the opening of stomata.

Response/Marking Scheme

Potassium ions enter guard cells, through a process which involves active transport and the consumption	2
of energy. (It is not known how the process is initiated). Since water moves passively, the	1
potassium ion concentration sets up a concentration gradient which favours the entry of water into the	2
guard cells. The water enters the guard cells very quickly after the potassium ions enter. As a result of increased turgor pressure in the guard cells, and	1
the presence of thicker, less extensible inner cell	1
walls, the guard cells assume the shape of two kidney beans creating an opening between them.	1
Possible:	8
Maximum:	6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.8
TOPIC: Structure/Function	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: guard cells stomata

Guideline Objective

The student will be expected to describe the structure of a leaf, the role and operation of the stomata, and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student will relate the structure of the guard cell to the function it performs in determining the size of the stomata.

Item

An important biological principle is that structure determines function. Using guard cells as an example, show how this principle applies to plants.

Response/Marking Scheme

The guard cells are shaped like a bean or banana, with the inner cell walls somewhat thickened. 1

If the volume of the cytoplasm inside the guard increases, the entire guard cell will become more banana-shaped: that is, more curved. 1

The alignment of two guard cells together is such that if they both become more curved, the size of the stoma(te) increases. 1

The guard cells possess chloroplasts in their cytoplasm, 1

whereas other cells of the epidermis do not. In the photosynthetic process, glucose is produced and converted into starch. 1

The relative amount of starch and glucose determine to a large extent the osmotic pressure exerted by the guard cells 1

on the epidermal cells in the vicinity. If a net movement of water occurs into the guard cells, the volume will increase, and the cell will become more curved: that is, the stomate will open. This will occur if carbohydrates are in the form primarily of glucose. 1

If glucose units are converted into starch units, the number of solute particles decreases and the osmotic pressure also decreases with respect to the surrounding epidermal cells. Thus a net movement of water occurs out of the guard cells resulting in a decrease in guard cell volume. This decrease results in the guard cells becoming less curved, causing the stomata to close. 1

An enzyme responsible for the conversion of starch to glucose and glucose to starch is affected by the pH of the cytoplasm. 1

The pH in turn is affected by the photosynthetic process which is primarily affected by the presence or absence of light. 1

Thus, the structural features of the guard cells such as: thickened inner cell wall, the presence of chloroplasts, the presence of enzymes which foster the conversion of starch to glucose and glucose to starch, and the absence of chloroplasts in epidermal cells other than guard cells, determines the function of guard cells with respect to their function of controlling the size of stomata. 1

Possible: 11

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.07
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.5, A.8, A.9, A.10, B.1, B.2, C.2, D.3, D.6, F.1
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photomicrograph leaf structure evolution

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

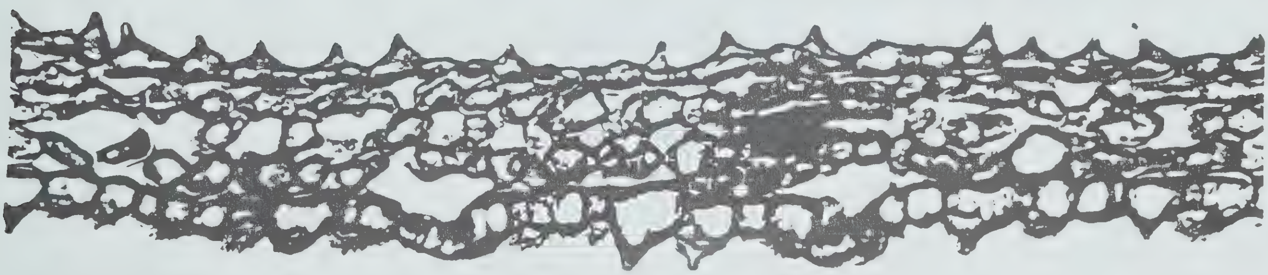
Item Focus

The student should be able to apply knowledge of leaf structure to a similar organ which has not yet been studied by the student.

Item

Refer to Figure 3K.6.

CROSS SECTION OF A FUSCHIA PETAL



A photomicrograph of a cross-section of a fuschia petal is provided in Figure 3K.6. While you have not studied petals, you have studied leaves.

Point out similarities and differences between the petal and a leaf. Discuss possible reasons for these similarities and differences.

Response/Marking Scheme

The petal possesses a loose layer of tissues 1
placed between two compact layers 1
and these resemble the mesophyll and upper and lower epidermis of the leaf. 1
The superficial similarity could be explained if the petals were seen as leaves modified by evolutionary forces 1
to perform new activities but still retaining structural vestiges of their evolutionary past. 1
However, there are no palisade cells 1
suggesting that the activity of photosynthesis is not carried out any more 1
but a reminder of the palisade cells remains in the greater compactness of the upper 'core' cells. 1
Since colour is always more intense at the upper surface of a petal than the lower, it seems that the mesophyll-like 'core' cells have retained some of the leaf activity of synthesizing and storing pigments. 1
However, there are no stomata or guard cells evident 1
and so it would seem that petals have a low respiratory rate relative to leaves 1
from which they likely evolved. This is supported by the <u>much</u> reduced vascular tissue. 1
There may be an attempt to reduce water loss compared to the transpiration of leaves. The reduced vascular tissue could indicate this, but the lack of vascular tissue may also suggest that evolutionary modification of leaves into petals occurred when plants were still confined to moist places 1
since hydrophytic leaves have little vascular tissue. 1

Total: 13

Maximum: 9

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbER.08
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, B.1, B.2
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata guard cells

Guideline Objective

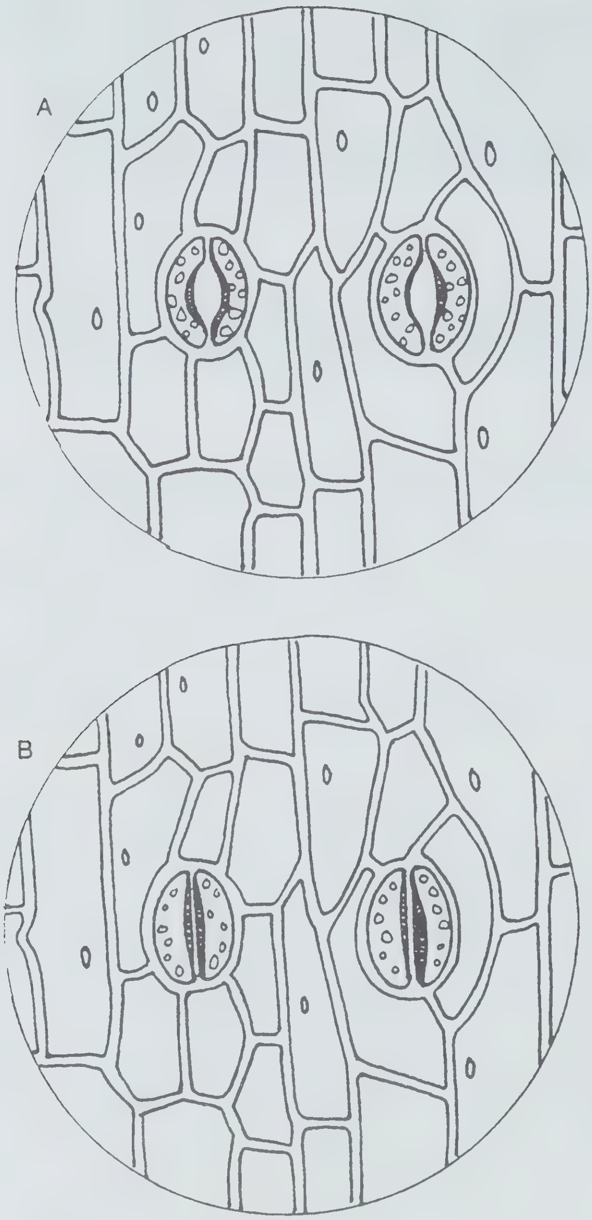
Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to describe the structure of the leaf and the role and operation of the stomata.

Item

Refer to Figure 3K.7.



A. Describe what is represented by each of the two figures.

B. Explain the situation which could cause the difference between the two figures.

C. Describe the mechanism involved in B.

Response/Marking Scheme

A. Both figures represent a surface, epidermal view 2

of a leaf. This is apparent from the presence of stomata. In Figure a, the stomata are in their opened condition and in Figure b, they are closed. 2

B. The situation which could result in the stomata to be as they appear in Figure a, would be one in which the plant would not be under any water stress. 1

The stomata are open, allowing free water vapour flow. In Figure b, the stomata are in their closed condition, to minimize the loss of water vapour 1 from the plant interior.

C. The stomata are in the open condition when the turgor pressure of the guard cells is greater than 2

that of the epidermal cells which surround them. 1

This causes the guard cells to change their shape, curving because of the thick inner walls resulting in a larger pore (stoma). 2

Conversely, when the guard cells have a lesser turgor pressure than the adjacent epidermal cells, 2

the guard cells become more flaccid, resulting 1

in the closing of the stoma. 1

Possible: 13

Maximum: 13

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbLP.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.2, A.3, A.7, B.1, B.2, C.4, D.3, G.1, G.2
TOPIC: Leaf Structure/Function	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis chlorophyll starch test lab

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to locate photosynthetic cells in variegated leaves, and perform a starch test to confirm.

Item

A. Draw and label a diagram of the leaf provided, indicating the regions of photosynthetic cells.

B. Using the materials provided, perform a test that would support your inferences about the photosynthetic regions of the leaf.

C. Prepare a concise report, listing the steps in your procedure, and giving the reason for each step. Explain why the test confirms your inferences about the sites of photosynthesis.

CAUTION: ETHANOL IS A VOLATILE LIQUID THAT EVAPORATES TO FORM A FLAMMABLE VAPOUR. IT MUST NEVER BE USED WITH AN OPEN FLAME. ASSURE ADEQUATE VENTILATION. WHEN HEATING MATERIALS, WEAR SAFETY GOGGLES, AND KEEP IN MIND THE HAZARDS TO YOURSELF AND THOSE NEARBY.

Response/Marking Scheme

A. Diagram with chlorophyll/non-chlorophyll regions identified as photosynthetic/non-photosynthetic sites. 2

C. Procedure:

1. Boil leaf in water	1
to kill leaf cells, making them permeable.	1
2. Boil leaf in ethanol	1
to dissolve chlorophyll, extracting it	1
to prevent masking the starch test.	1
3. Wash leaf and iodine solution	1
to test for starch.	1
Diagram showing the regions of positive starch test coinciding with regions of chlorophyll.	2
Confirms that photosynthesis occurred in the regions of chlorophyll, since starch was formed from the sugar produced there, and not elsewhere.	2
Possible:	13
Maximum:	10

Teacher Notes

In this simple laboratory problem, you are to provide your students with a variegated leaf, and the materials for them to perform a starch test. Leaves from variegated coleus, geranium, impatience, or other plants are suitable. The plants should have been in bright light for several hours.

CAUTION: ETHANOL IS A VOLATILE LIQUID THAT EVAPORATES TO FORM A FLAMMABLE VAPOUR. IT MUST NEVER BE USED WITH AN OPEN FLAME. ASSURE ADEQUATE VENTILATION. WHEN HEATING MATERIALS, WEAR SAFETY GOGGLES, AND KEEP IN MIND THE HAZARDS TO YOURSELF AND THOSE NEARBY.

Materials:

	leaf	white tile
2	beakers, 250 and 500 mL	ethanol
	hot plate	iodine solution
	water bath	forceps
	goggles	

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Leaf Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS:

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the functions of parts of a leaf with the appropriate function.

Item

In the space provided, select the appropriate function from the parts of a leaf listed in Column A. Do not use an expression from Column B more than once.

Column A
1._____xylem cells
2._____epidermal cells
3._____guard cells
5._____phloem cells
4._____mesophyll cells
6._____stomata
7._____epidermal hair

Column B
A. usually open in darkness
B. carry water to all parts of the leaf
C. contain chlorophyll for photosynthesis
D. responsible for leaf fall
E. usually open in the light
F. control exchange of gases
G. synthesize cuticle
H. can carry mineral ions out of leaf
I. trap air next to the leaf surface

Response/Marking Scheme

Correct responses:

1.- B, 2.- G, 3.- F, 4.- C, 5.- H, 6.- E, 7.- I

Possible: 7

Maximum: 7

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbMA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: MA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Plant Cell Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: plant cell plasmodesma

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

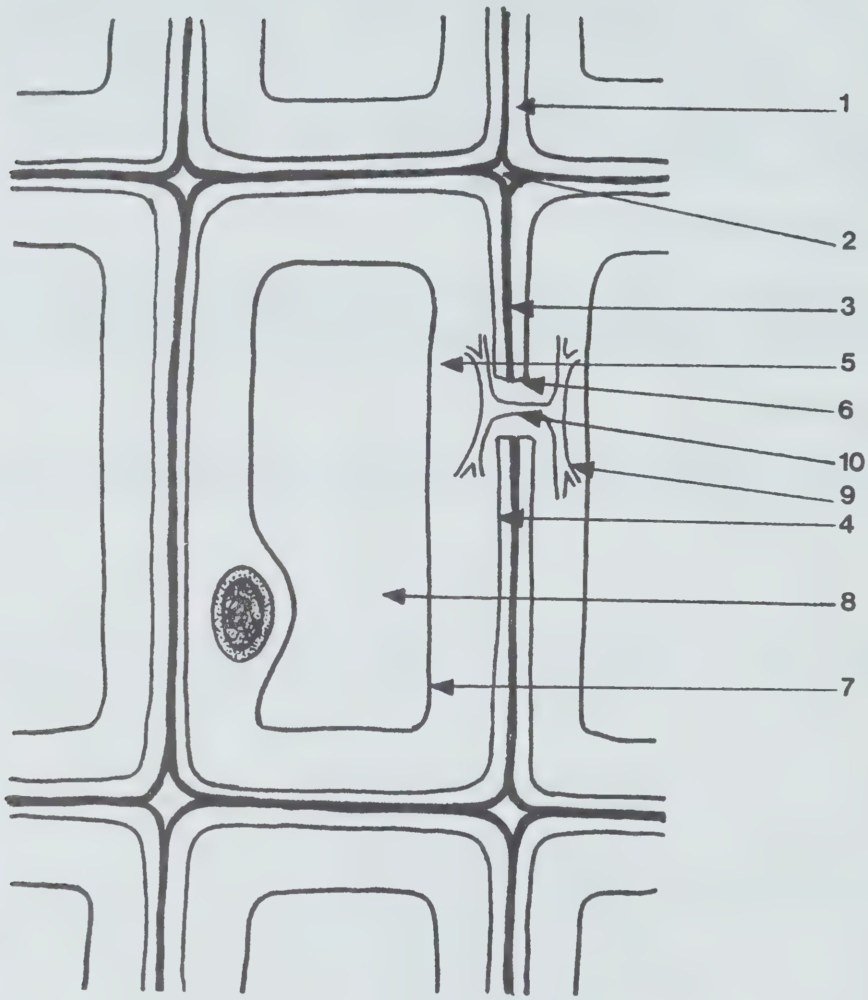
Item Focus

The student should be able to match labels with numbers on a diagram of a plant cell.

Item

Refer to Figure 3K.42

A PLANT CELL



Select a label from the list below and match each one with a numbered structure on Figure 3K.42. The labels are as follows:

central vacuole
cytoplasm
desmotubule
plasma membrane
air space
plasmodesma
cell wall
vacuolar membrane
middle lamella
endoplasmic reticulum

Place your answers in the spaces provided:

1. ______________________________

2. ______________________________

3. ______________________________

4. ______________________________

5. ______________________________

6. ______________________________

7. ______________________________

8. ______________________________

9. ______________________________

10. ______________ ______________

Response/Marking Scheme

1. cell wall
2. air space
3. middle lamella
4. plasma membrane
5. cytoplasm
6. plasmodesma
7. vacuolar membrane
8. central vacuole
9. endoplasmic reticulum
10. desmotubule

Possible: 10

Maximum: 10

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb 32c
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.6, A.10, B.1
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: leaf structure stem

Guideline Objective

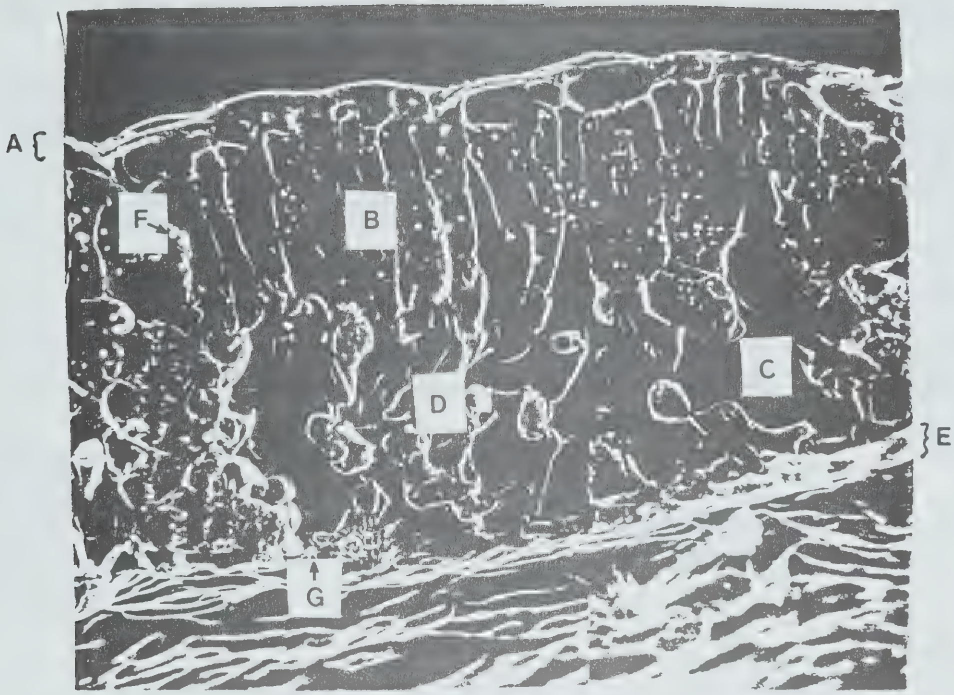
Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify tissues seen with the scanning electron microscope (SEM) from knowledge of their appearance with the light microscope.

Item

Refer to Figure 3K.8.



The scanning electron microscope (SEM) micrograph which appears in Figure 3K.8, contains a number of structures you have studied with the light microscope. Write an appropriate title and labels in the spaces provided.

Response/Marking Scheme

Title:	Cross Section of a Mesophytic Leaf	2
A.	upper epidermis	1
B.	palisade mesophyll	1
C.	air space	1
D.	spongy mesophyll	1
E.	lower epidermis	1
F.	chloroplast	1
G.	stoma	1
	Possible:	9
	Maximum:	7

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Leaf Structure and Carbon Dioxide Uptake	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: dicotyledonous mesophytic

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to name the source of carbon dioxide, and trace its pathway into the cells in the middle of a leaf, listing the factors that may affect its uptake.

Item

A. What are two possible sources of carbon dioxide for a terrestrial plant?

B. Describe in detail the path taken by carbon dioxide from outside the plant until it reaches the site in a dicotyledonous, mesophytic leaf where it is used for photosynthesis. How does the carbon dioxide move?

C. List five factors that may affect the rate of uptake of carbon dioxide by the plant.

Response/Marking Scheme

A. The air surrounding the plant, and also 1
from aerobic respiration in the mitochondria of the cells. 1

B. Molecules of gaseous carbon dioxide diffuse in the air that enters the leaf through the stomata, which are found mostly in the lower epidermis. 2

Continues by gaseous diffusion through the intercellular air spaces of the spongy mesophyll to palisade cells. 2

The gas dissolves in water in the cellulose wall of the cells, and diffuses in solution through the plasma membrane. 2

Carbon dioxide continues to diffuse in solution through the cytoplasm and through the membrane surrounding the chloroplast, into the stroma, where it is used in photosynthesis. 2

C. light intensity
wavelength (colour) of light
temperature
concentration of carbon dioxide
concentration of oxygen
size of the stomatal openings 6

Possible: 16

Maximum: 12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Plant Structure/Function
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KbSA.03
GUIDELINE OBJECTIVE CODE: 31Kb
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10, B.1, B.2
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: stomata guard cells

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the structure of the leaf and describe the role each leaf tissue plays in the leaf.

Item

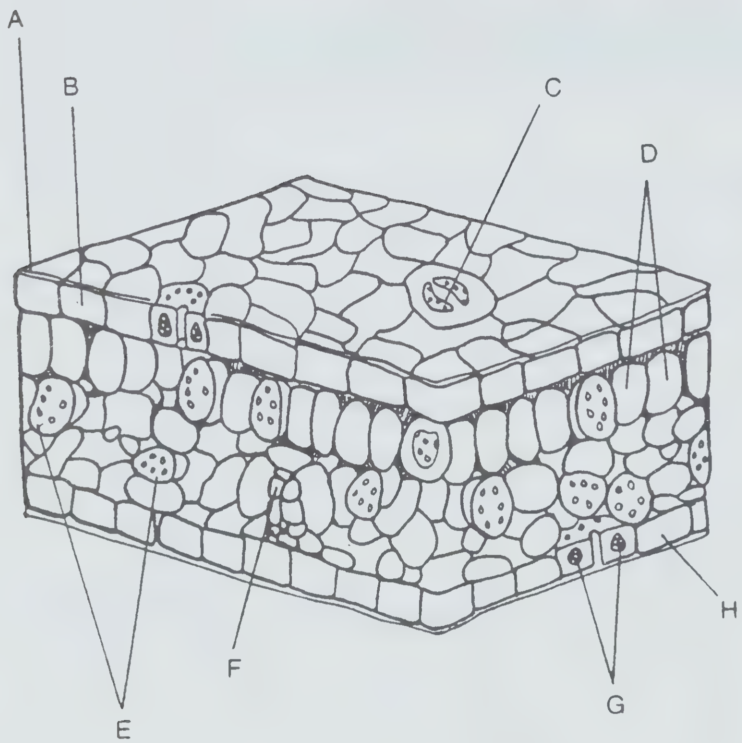
Refer to Figure 3K.9.

A. Supply a title, label the parts indicated and label each type of each tissue represented.

B. Describe the role of each tissue type indicated in A.

Figure 3K.9

TITLE: ______________________________



A ______________________________

B ______________________________

C ______________________________

D ______________________________

E ______________________________

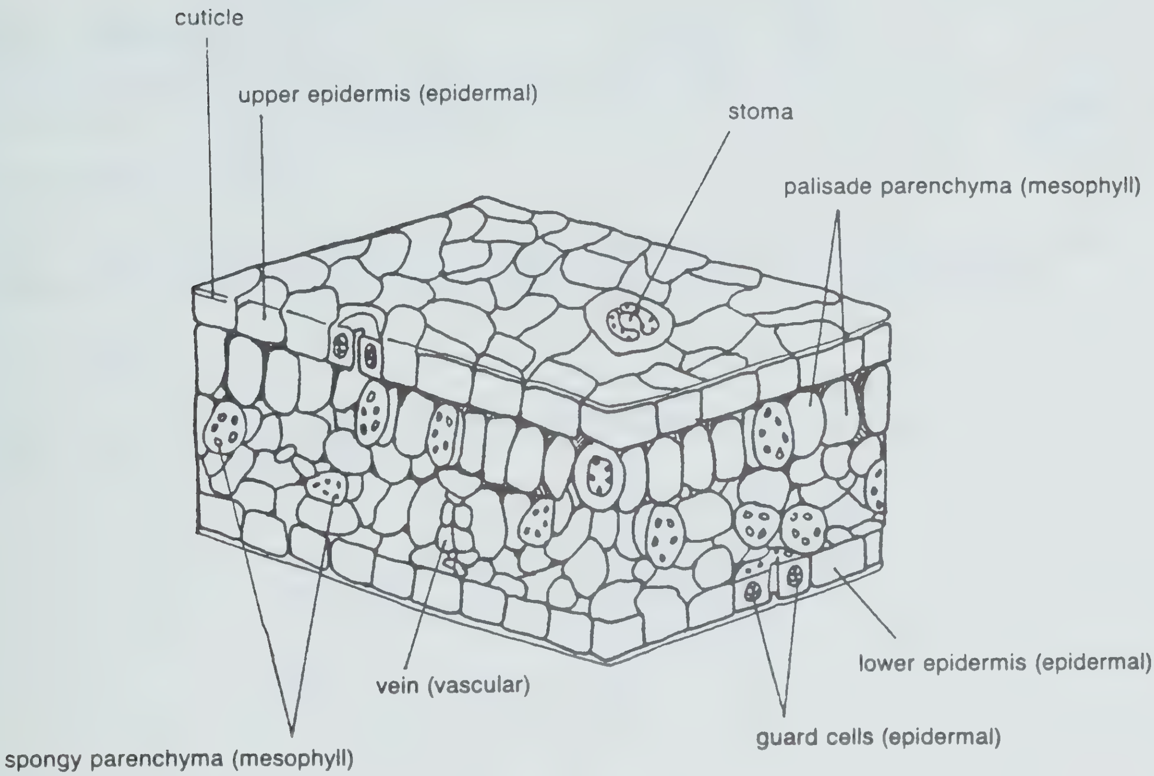
F ______________________________

G ______________________________

H ______________________________

Response/Marking Scheme

BLOCK DIAGRAM OF THE TISSUES OF A LEAF



Possible: 14

Maximum: 14

Diagram redrawn from *Botany* Weier, Stocking and Barbour, Wiley and Sons, 1970.

B. Epidermis with its cuticle provides an outer covering for the leaf, reducing uncontrolled loss of water vapour, and protecting against bacterial and fungal infection and minor abrasion. 3

<u>Mesophyll</u>, carries on photosynthesis and supports 1

the leaf blade because of its turgor.	1
<u>Vascular tissue</u>, xylem and phloem support the blade	1
and conduct water and manufactured products.	1
Possible:	7
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KbSA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, B.1, B.2
TOPIC: Plant Structure/Function	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stomata guard cells

Guideline Objective

Students will be expected to describe the structure of a leaf, the role and operation of the stomata and the role each different kind of leaf tissue plays in photosynthesis.

Item Focus

The student should be able to identify the structure of the leaf and describe the role each leaf tissue plays in the leaf.

Item

Refer to Figure 3K.10.

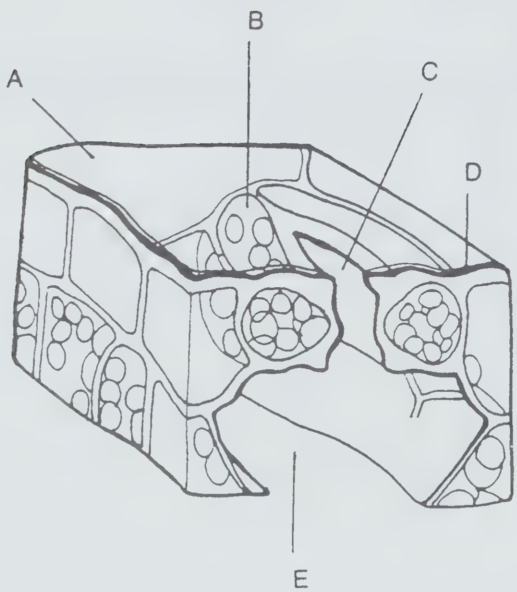
A. Supply a title and identify the parts indicated.

B. Describe the functions of B, C, D, and E.

Figure 3K.10

A.

TITLE ______________________



A ______________________

B ______________________

C ______________________

D ______________________

E ______________________

Response/Marking Scheme

A.

Title: Block Diagram of a Section of Leaf Tissue Showing the Structure of Guard Cells — 2

Labels: A. epidermal cell
B. guard cell
C. stoma
D. cuticle
E. air space (stomatal chamber) — 5
(substomatal space)

B.

Guard Cell, regulates the opening and closing of the stoma.	1
Stoma, a pore through which gas exchange occurs.	1
Cuticle, a waxy covering which reduces the movement of water and gases, protects against abrasion and bacterial infection.	2
Air Space, provides air passageways throughout the leaf to allow gases to diffuse to and from cells and the exterior.	1
Possible:	12
Maximum:	12

Diagram redrawn from *Botany*, Weier, Stocking, and Barbour, Wiley and Sons, 1970, page 94.

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light-dependent reactions

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

Students should be able to identify the characteristics of the light-dependent reactions of photosynthesis.

Item

Which one of the following statements is <u>NOT</u> a characteristic of the light-dependent reactions of photosynthesis?

☐ A. The process takes place in the thylakoids of the chloroplasts.

☐ B. Energy is converted from a physical to a chemical form.

☐ C. Reduction takes place.

☐ D. Carbon fixation occurs.

☐ E. Electrons are displaced.

Response/Marking Scheme

Correct response: D

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: thylakoid light-independent reactions carbon fixation

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to identify the characteristics of the light-independent (dark) reactions of photosynthesis.

Item

Some of the following statements are characteristics of the light-independent reactions of photosynthesis:

I The process takes place in the thylakoids of the chloroplasts.
II Carbon fixation occurs.
III Photophosphorylation takes place.
IV Oxygen is a product of the reactions.
V Reduction takes place.
VI The process produces NADPH + H^+
VII ATP molecules are required to drive the reactions.

Which of the above are correct?

☐ A. I, III, and IV only

☐ B. I, II, and VII only

☐ C. II, V, and VII only

☐ D. III, IV, and VI only

☐ E. II, V, VI, and VII only

Response/Marking Scheme

Correct response: C

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photolysis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KcMC.03
GUIDELINE OBJECTIVE CODE: 31Kc
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: chlorophyll excitation

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to identify the function of light in photosynthesis.

Item

The step in photosynthesis immediately concerned with light is the

☐ A. regeneration of chlorophyll

☐ B. excitation of chlorophyll

☐ C. transfer of energy from chlorophyll to water

☐ D. fixation of carbon dioxide

☐ E. production of energy.

Response/Marking Scheme

Correct response: B

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: energy conversion.

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to describe the first step in trapping the energy of sunlight.

Item

What is the first step in the conversion of energy when sunlight falls on a leaf?

Response/Marking Scheme

When a photon of light of suitable wavelength	1
strikes a chloroplast in the mesophyll cells	1
a molecule of chlorophyll a (photosystem 11)	1
becomes excited (raised to a higher energy level).	1
In this activated state, the chlorophyll splits a water molecule	1
making electrons and hydrogen atoms available	2
- a source of chemical potential energy.	1
Possible:	8
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc 21Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, F.1
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photosynthesis respiration chlorophyll

Guideline Objective

Students will be expected to compare, in general terms, the “light” (light-dependent) and “dark” (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to account for the interrelationship of photosynthesis and respiration.

Item

The following statements concern photosynthesis and/or respiration. Indicate whether each statement is true or false, and justify your choice.

A. Since the reactants of photosynthesis are the products of respiration, and vice versa, therefore photosynthesis is respiration in reverse.

B. Chlorophyll provides the energy required for photosynthesis.

Response/Marking Scheme

A. False 1

The reactions themselves are not the reverse of one another. Both reactions function in only one direction. 1

They use different enzymes and occur in different 1

sites. 1

They use different energy sources. 1

B. False 1

Light provides the energy. 1

The role of chlorophyll is to convert light energy 1

to chemical energy which can be utilized by the plant. 1

Possible: 9

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photosynthesis equation

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to contrast the summary equation for photosynthesis with the details of the process.

Item

A. Write the overall equation for photosynthesis.

B. Suggest three ways in which the overall equation for photosynthesis is misleading.

Response/Marking Scheme

A. $6H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2$ 2

or

$12H_2O + 6CO_2 \rightarrow C_6H_{12}O_6 + 6O_2 + 6H_2O$

B. It fails to represent the complexity of the process. 1

It does not show the many intermediate products. 1

It implies that carbon dioxide and water combine directly. 1

Possible: 5

Maximum: 5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcSA.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light-dependent reaction light-independent reaction

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light dependent) and "dark" (light independent) reactions of photosynthesis.

Item Focus

The student should be able to contrast the light-dependent and light-independent reactions.

Item

Using a table, contrast the light-dependent and light- independent reactions of photosynthesis under the following headings:

A. reactants,
B. energy source,
C. products.

Response/Marking Scheme

	LIGHT-DEPENDENT	LIGHT-INDEPENDENT	
A. Reactants	water	carbon dioxide	
	electron (chlorophyll)	ribulose diphosphate	
	NADP		
	ADP + phosphate		7
B. Energy source	light	ATP	
		NADPH + H^+	3
C. Products	NADPH + H^+	PGAL (glucose)	
	ATP	ADP + phosphate	
	Oxygen	NADP	7
		(ribulose phosphate)	

Possible: 17

Maximum: 12

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KcSA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kc
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photoreduction

Guideline Objective

Students will be expected to compare, in general terms, the "light" (light-dependent) and "dark" (light-independent) reactions of photosynthesis.

Item Focus

The student should be able to identify the role of light and water in the process of photosynthesis.

Item

A. What is the role of light in photosynthesis?
B. What is the role of water in photosynthesis?

Response/Marking Scheme

A.	Light is the source of energy,	1
	and energy is essential for synthesis, since	1
	energy excites the electrons of chlorophyll	1
	and results in splitting water molecules.	1
B.	Water is the source of hydrogen ions and electrons	2
	which are needed for reduction.	1

Possible: 7

Maximum: 5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Plants in the Biosphere	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: production of oxygen

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

The student should be able to recognize the overall importance of photosynthesis.

Item

The overall reason why photosynthesis is important for the biosphere is because it produces

☐ A. ATP.

☐ B. reduced NAD.

☐ C. carbon dioxide.

☐ D. oxygen.

☐ E. both ATP and oxygen.

Response/Marking Scheme

Correct response: D

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Plants in the Biosphere	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: biosphere photosynthesis

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

Students should be able to identify the role of plants in the biosphere.

Item

Living plants are essential in the biosphere because they are a major source of

I molecular oxygen
II carbon dioxide
III fixed carbon
IV water
V nitrogen

Choose your answer from the following

☐ A. I only

☐ B. II and IV only

☐ C. III and IV only

☐ D. I and III only

☐ E. I, III and V only

Response/Marking Scheme

Correct response: D

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10.
TOPIC: Importance of Plants	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: biosphere oxygen photosynthesis

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

The student should be able to identify the importance of plants in the biosphere.

Item

"All organisms on this planet depend on plants for their survival."

Discuss three different ways of justifying the above statement in terms of the process of photosynthesis.

Response/Marking Scheme

1. During photosynthesis, the chlorophyll molecules in the chloroplasts of the green cells of plants convert light energy into chemical potential energy. 2

   This energy, in the bonds of organic molecules, is the source of almost all the energy used by living organisms. 1

2. Photosynthesis converts the carbon of inorganic carbon dioxide into the carbon of organic molecules, e.g., carbohydrates, fats, proteins, and vitamins. 2

   This is the only source of carbon available for the synthesis of the organic molecules essential for the life of all organisms. 1

3. Photosynthesis breaks down the molecules of water, releasing oxygen, replenishing the atmospheric oxygen used by aerobic organisms. 2

   Thus plants maintain the essential concentration of oxygen necessary for life on this planet. 1

   Alternate:
   The synthesis of cellulose and lignin by plants, using the energy and products of photosynthesis provides wood that is the source of shelter for a great many organisms, both during the life of the plant, and after it dies. 2

   Humans and many other organisms make use of these building materials to shelter themselves from the elements,
   enhancing their opportunities to survive in a wide range of climates. 1

Possible: 3 @ 3 Marks Each = 9

Maximum: 9

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Importance of Plants	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: biosphere

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

Same as above.

Item

Give four major reasons why plants are essential to the biosphere.

Response/Marking Scheme

Plants are important to the biosphere for the following reasons (accept any 4, such as:)

1. They directly, or indirectly provide food for all of the animals on Earth, including humans. 2
2. Through the process of photosynthesis, plants trap the energy from the sun and make it available to other organisms. Without this energy trapping mechanism, life, as we know it would cease to exist on Earth. 2
3. Plants release large amounts of oxygen. Plants take the waste end products of animal respiration, and use them in the photosynthetic process. The oxygen end product of this latter process enables animals (and plants) to carry on the process of respiration. (OR plants play an important role in the oxygen/carbon cycle) 2
4. Plants serve as a carbon dioxide "sink" trapping and holding large quantities of carbon dioxide or carbonates. Without plants, the amount of carbon dioxide present in the atmosphere would be much higher than it presently is. Atmospheric carbon dioxide, in turn, could have adverse effects on the biosphere (greenhouse effect). 2
5. Plants and plant products serve as homes for many organisms, providing sheltered environments for others, as well as materials for many different organisms. 2
6. Plants retain water in ecosystem, minimizing erosion and run-off, and ensuring steady flow of streams. 2
7. Plants accumulate ions from the environment, making them available for biogeochemical cycling. 2

Possible: 8

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Plants in the Biosphere	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: biosphere

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

The student should be able to list 5 reasons why plants are essential in the biosphere.

Item

List five different reasons why plants are important for life in the biosphere.

Response/Marking Scheme

accept any 5, such as:

Plants

-fix energy for other trophic levels
-re-circulate chemical elements for other trophic levels
-retrieve minerals leached into soil depths
-increase porosity of soil to air and water
-provide humus for mineral/water retention in soil
-provide shelter for animals
-ameliorate the environment for other life forms
-provide molecular oxygen to the atmosphere
-generate defensive chemicals sometimes used by animals

Possible: 5

Maximum: 5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KdER.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, I.4, I.5
TOPIC: Plants in the Biosphere	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: biosphere

Guideline Objective

Students will be expected to explain why plants are essential in the biosphere.

Item Focus

Same as above.

Item

Suppose a new fire retardant which is dropped from planes onto forest fires were found to block the cytochrome transport chain in Photosystem II. Discuss the advantages and disadvantages of introducing the new product to the ecosystem.

Response/Marking Scheme

Advantages: stops the forest fire, reducing damage by heat and flame.	1
Disadvantages: Plants affected by the chemical which survived the fire would have the photochemical reaction of photosynthesis blocked.	1
This would result in a reduction of the amount of oxygen released	1
and in the amount of carbon fixed in that ecosystem.	1
It would also result in the disruption in the major biogeochemical cycles.	1
Possible:	5
Maximum:	4

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Chloroplast Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: grana thylakoid

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to identify terms used to describe the structure of a chloroplast.

Item

The flattened membranous sacs which form the grana within many chloroplasts are called

☐ A. reaction centres.

☐ B. thylakoids.

☐ C. carotenoids.

☐ D. photosystems.

☐ E. stroma.

Response/Marking Scheme

Correct response: B

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Chloroplast Structure
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KeMC.02
GUIDELINE OBJECTIVE CODE: 31Ke
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: ATP

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to identify the functioning of specific parts of the chloroplast.

Item

If the membrane structure inside a chloroplast breaks down, the part of photosynthesis most likely to be affected would be the

- [ ] A. production of oxygen.
- [ ] B. production of ATP.
- [ ] C. absorption of light.
- [ ] D. oxidation of chlorophyll.
- [ ] E. activation of accessory pigments.

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Chloroplast Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: grana

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to distinguish between parts of a chloroplast.

Item

The stacks of photosynthetic membranes inside a chloroplast are called

- [ ] A. grana.
- [ ] B. cristae.
- [ ] C. lamellae.
- [ ] D. vesicles.
- [ ] E. stroma.

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Chlorophyll Structure/Function
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KeMC.04
GUIDELINE OBJECTIVE CODE: 31Ke
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, D.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: fluorescence

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to identify an explanation of the fluorescence of chlorophyll.

Item

If chlorophyll is isolated in a test tube and exposed to light, it re-emits this energy in a visible fluorescence. These data show that

☐ A. isolated chlorophyll converts the absorbed light into useful chemical energy.

☐ B. the light emitted is of the same frequency as the light striking the chlorophyll.

☐ C. intact chloroplasts are necessary for photosynthesis to take place.

☐ D. chlorophyll must work along with other molecules such as NADP to trap light energy.

☐ E. the energy of excited electrons is released as photons of light when the electron carriers are disrupted.

Response/Marking Scheme

Correct response: E

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11
TOPIC: Photosynthesis	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photosynthesis chloroplasts grana

Guideline Objective

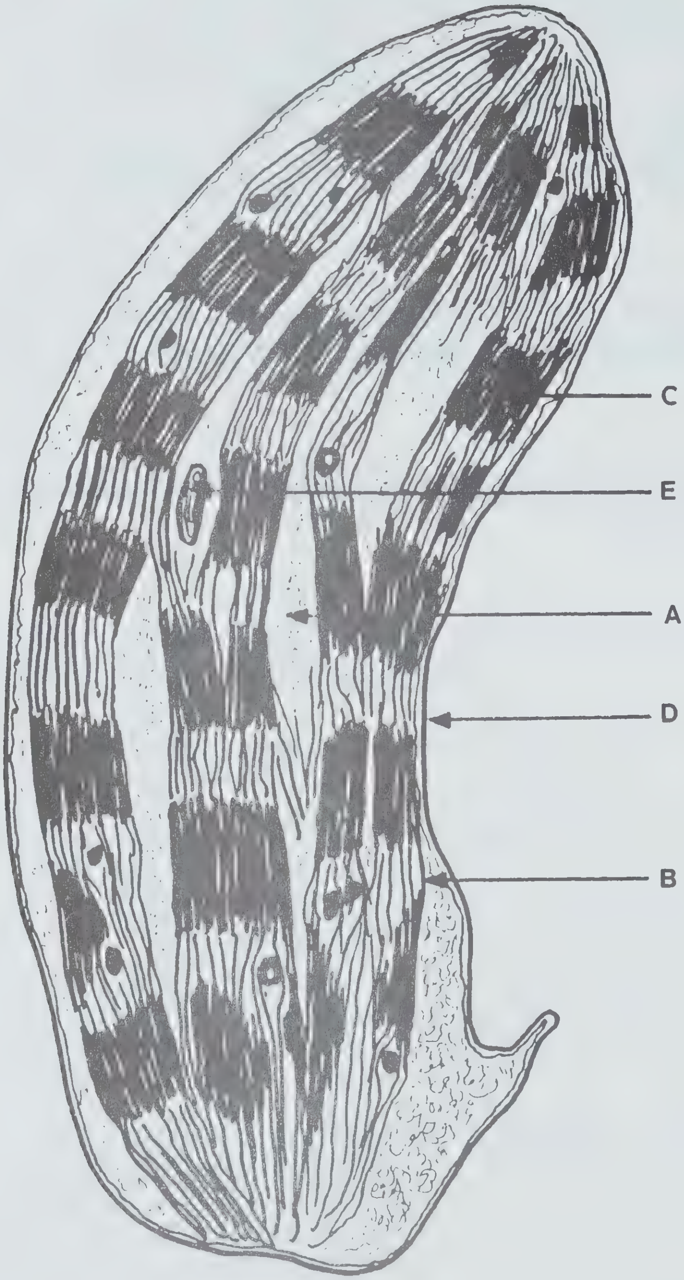
Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to identify the structure of the chloroplast and describe the location where light reactions take place.

Item

Refer to Figure 3K.11.



The structure in Figure 3K.11 responsible for light-dependent reactions is:

- [ ] A. 1
- [ ] B. 2
- [ ] C. 3
- [ ] D. 4
- [ ] E. 5

Response/Marking Scheme

Correct response: C

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeDL.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: DL
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11
TOPIC: Structure/Function	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Communication	TIME ALLOCATION:

KEYWORDS: chloroplasts

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to draw and label the structure of a chloroplast, and indicate the site of the light-dependent reactions.

Item

A. Draw and label the internal structure of a chloroplast.

B. Where, in your diagram, is the site of the light-dependent ("light") reaction of photosynthesis?

Response/Marking Scheme

A. Diagram — 2

Labels: double membrane
granum
thylakoid
lamella (inter grana lamella)
stroma (fluid matrix) — any 4

B. Site of reaction: thylakoid membrane — 1

Possible: 7

Maximum: 7

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KeER.01
GUIDELINE OBJECTIVE CODE: 31Ke,
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, A.5, A.9, E.1
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: oxidation reduction light-dependent reaction thylakoid.

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to explain the role of oxidation-reduction reactions in light-dependent photosynthesis.

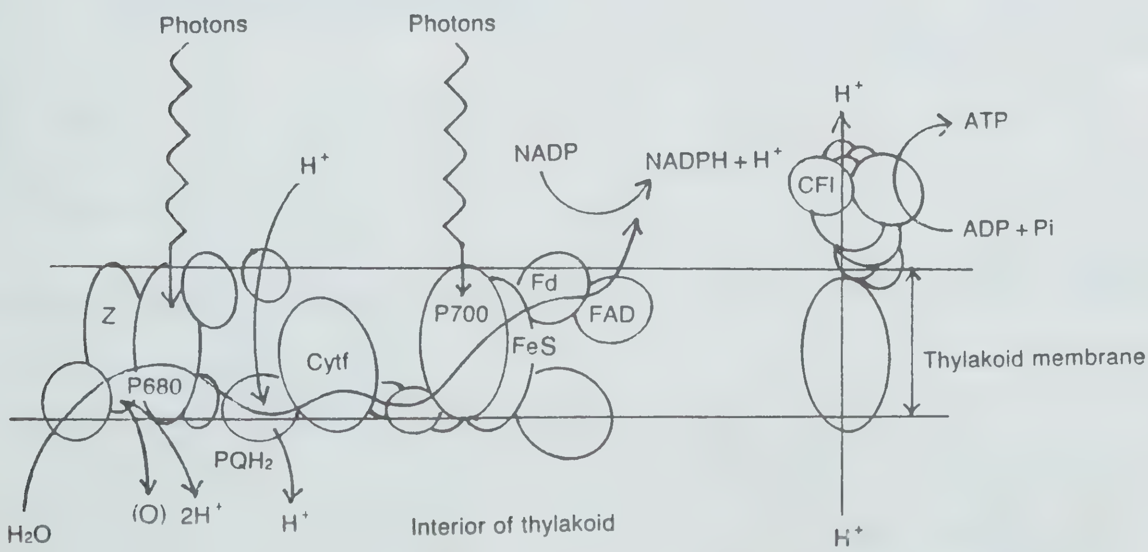
Item

Refer to Figure 3K.12.

Oxidation-reduction reactions are instrumental in the transfer and transformation of energy within living structures.

Explain with the aid of the model how the transformation of energy in photosynthesis depends on oxidation-reduction reactions.

THE LIGHT DEPENDENT REACTIONS OF PHOTOSYNTHESIS



Response/Marking Scheme

Light energy of the 680 and 700 nm frequencies raises the electrons of the antenna molecules of chlorophylls and xanthophylls to a higher energy state.	2
Molecular complexes within the membrane, next to the antenna molecules, that are more highly oxidized, capture the electrons, thereby becoming reduced and making the antenna molecules temporarily oxidized.	2
The antenna molecules now take electrons from another contiguous molecular neighbour. This transfer of electrons continues in a chain until a plentiful supply of electrons is found in a molecule with a low affinity for the electrons, water.	2
The transfer of electrons is always from reduced molecules (with a lower affinity for electrons) to an oxidized molecule (with a high affinity for electrons).	1
The final reduced molecule must be one not associated with the thylakoid membrane, one that can diffuse away to be used elsewhere in metabolism, in this case, the light-independent reaction.	1
Energy is lost as electrons pass down the chain, at each step of the oxidation-reduction process. Light provides the continuous source of energy for the reactions.	2
At the same time, the energy generated by the oxidation-reduction reactions drives hydrogen ions (protons) across the thylakoid membrane, thereby creating a difference in concentration of hydrogen ions, a difference in potential electrical charge. This potential difference is used in phosphorylating ADP to make ATP, the energy currency of the cell.	2
Possible:	12
Maximum:	8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeMA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke 31Kg 31Kh
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	INSTRUMENT TYPE: MA
	KLOPFER: A.1, A.2, A.9
TOPIC: Chloroplast Structure	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: stroma thylakoid grana

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to identify parts of the process of photosynthesis with specific sites in the chloroplast.

Item

From the list of specific structures on the right, select the letter that describes the site of the particular function, and enter the letter in the correct blank on the left.

1. C location of chlorophyll	A. stroma
2. A location of carbon fixation	B. outer membrane of the chloroplast
3. ___ location of ATP-ase enzymes	C. thylakoid membrane
4. ___ location of a high concentration of hydrogen ions for ATP synthesis	D. the cytoplasm
	E. interior of the thylakoid disc
	F. grana

Response/Marking Scheme

1: C, 2: A, 3: C, 4: E

Possible: 4

Maximum: 4

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Chloroplast	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chloroplast

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

Item Focus

The student should be able to label an electron photomicrograph of a chloroplast and indicate where the light dependent and light independent reactions take place.

Item

Refer to Figure 3K.13.

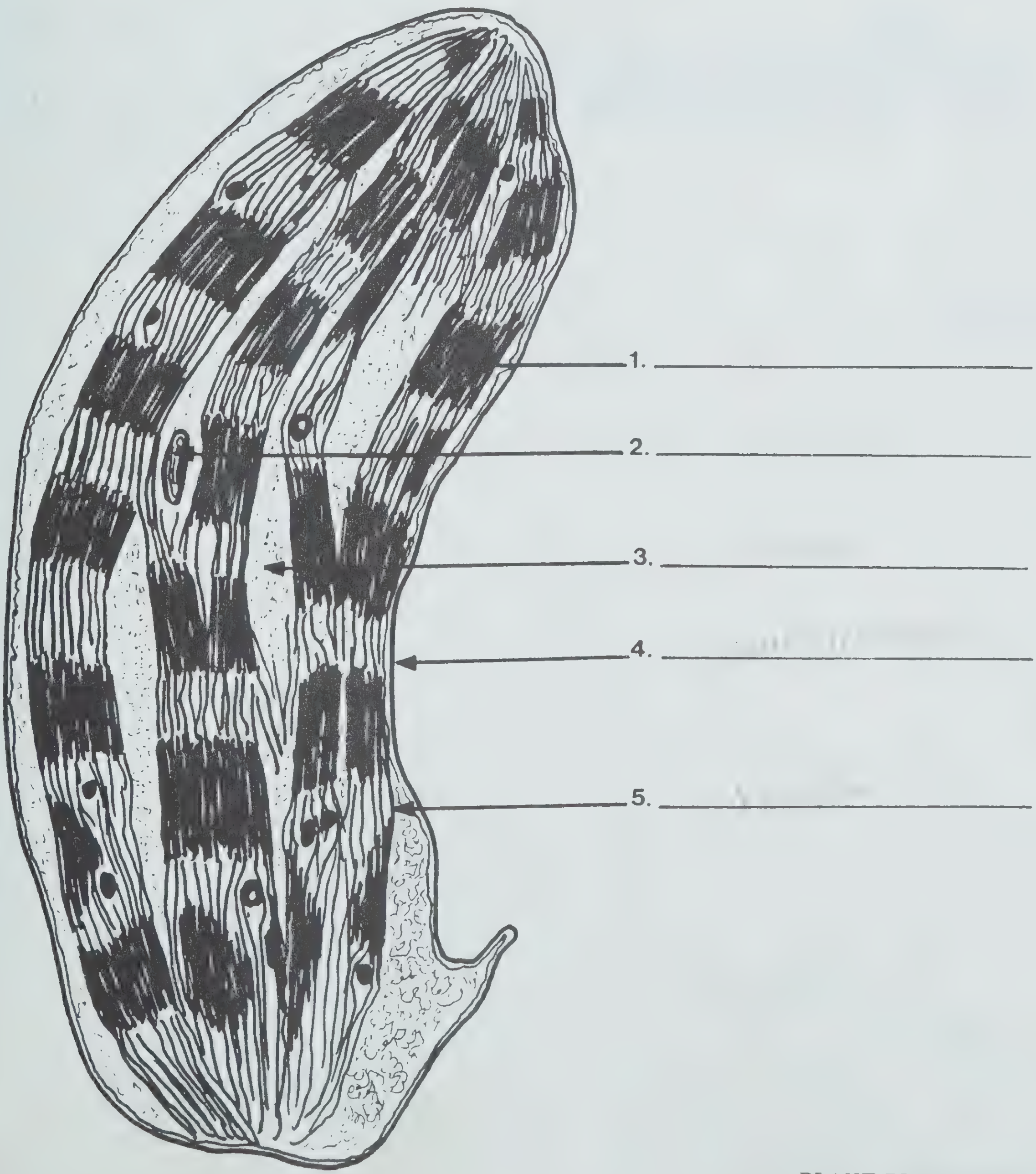
A. Label and title Figure 3K.13 in the spaces provided.

B. Indicate clearly on the micrograph where,

i) the light-dependent ("light") reactions take place.

ii) the light-independent ("dark") reactions occur.

____



Response/Marking Scheme

Title: A chloroplast, as shown by an electron microscope. 2

Labels:

1. grana
2. starch grain
3. stroma
4. plastid membrane
5. lamella 5

i) Site of light-dependent reactions: grana 1

ii) Site of light-independent reactions: stroma 1

Possible: 9

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KeSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ke 31Kg 31Kh
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	INSTRUMENT TYPE: SA
	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Chloroplast	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: thylakoid disc

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

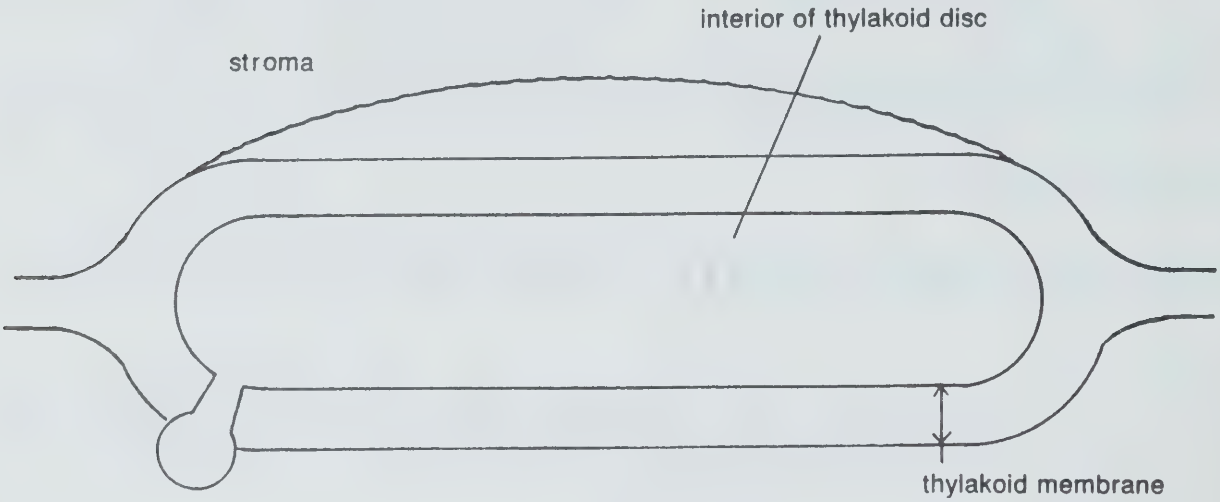
Item Focus

The student should be able to identify the exact sites of components of the photosynthetic process, given a diagram of a thylakoid disk.

Item

Refer to Figure 3K.14.

SECTION THROUGH A THYLAKOID DISC



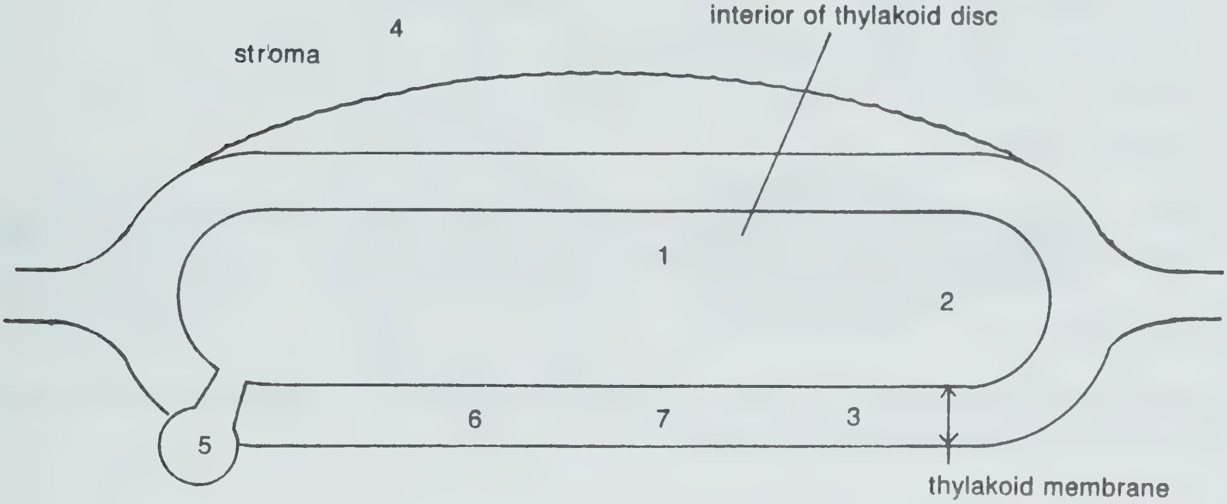
On the figure, place the numbers corresponding to the terms in the list below in their correct locations.

1. reservoir of hydrogen (hydronium) ions
2. photolysis
3. non-cyclic electron flow
4. carbon fixation
5. production of ATP
6. chlorophyll molecules
7. cyclic electron flow

Response/Marking Scheme

1 mark for each number correctly placed on the diagram (see Figure 3K.14).

SECTION THROUGH A THYLAKOID DISC



Possible: 7

Maximum: 7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Structure/Function
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KeSA.04
GUIDELINE OBJECTIVE CODE: 31Ke
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.11
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: chloroplasts

Guideline Objective

Students will be expected to recall the structure of a chloroplast and describe the locations where light-dependent and light-independent reactions take place.

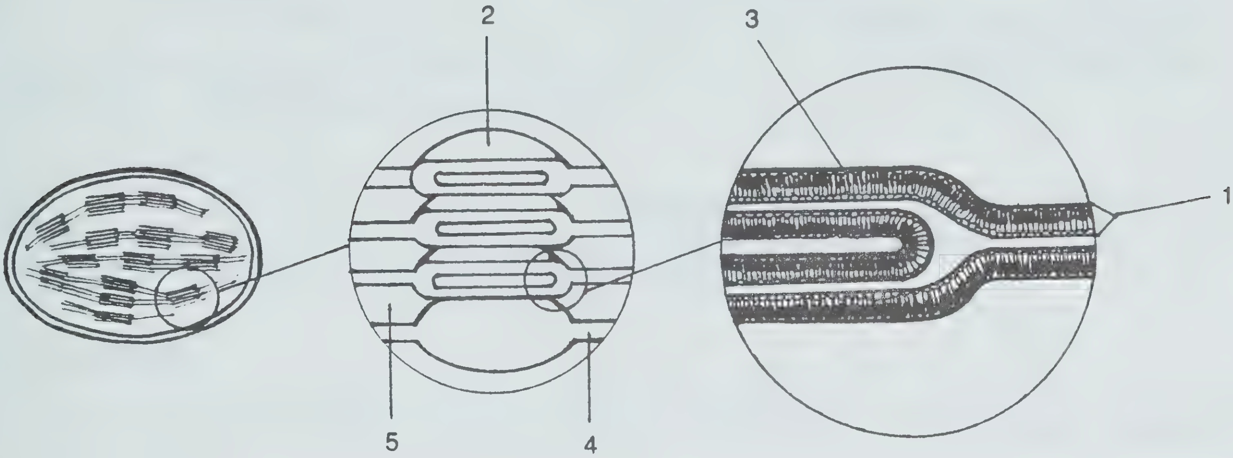
Item Focus

The student should be able to identify and label the structure of a chloroplast, and indicate the site of the light-dependent reactions.

Item

Refer to Figure 3K.15.

Title: ____



Labels:

1 _______________

2 _______________

3 _______________

4 _______________

5 _______________

A. Provide an appropriate title for Figure 3K.15. Label the internal structure shown in the figure.

B. Where, in the diagram, is the site of the light dependent ("light") reaction of photosynthesis?

Response/Marking Scheme

A. Title: Internal structure of a chloroplast — 2

Labels: double membrane — 5

granum

thylakoid

lamella (inter grana lamella)

stroma (fluid matrix)

B. Site of reaction: thylakoid membrane — 1

Possible: 8

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Absorption Spectrum
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KfMC.01
GUIDELINE OBJECTIVE CODE: 31Kf
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: `L
TIME ALLOCATION:

KEYWORDS: wavelength graphical analysis

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

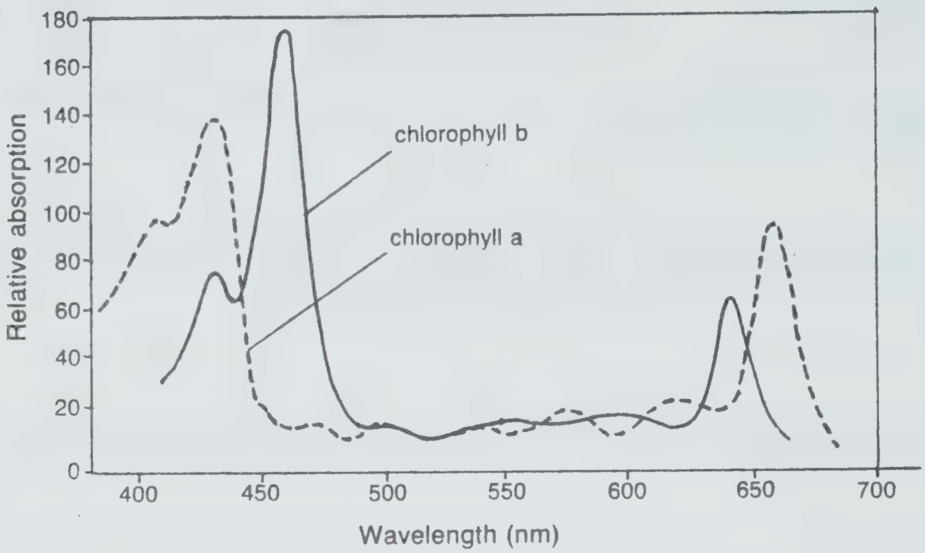
Item Focus

The student should be able to identify wavelengths of light that favour photosynthesis, given experimental data.

Item

Refer to Figure 3K.16 to answer this question.

ABSORPTION SPECTRA OF CHLOROPHYLL MOLECULES



Colour (subjective)	Wavelength (nm)
Deep Red	750
Red	650
Yellow	590
Green	540
Blue	490
Violet	430

From Figure 3K.16, it can be seen that Chlorophyll *a* is more effective in absorbing light in the ______________ wavelength of the visible spectrum while Chlorophyll *b* is more effective in the ______________ wavelength of light.

☐ A. red, blue

☐ B. violet, blue

☐ C. green, red

☐ D. blue, violet

☐ E. red, red.

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KfMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kf
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Absorption Spectrum	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: quality of light

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

The student should be able to identify the quality of light most effective for photosynthesis.

Item

The most effective portion of the spectrum for photosynthesis is the

☐ A. wavelengths shorter than the visible spectrum.

☐ B. wavelengths longer than the visible spectrum.

☐ C. yellow portion of the spectrum.

☐ D. red portion of the spectrum.

☐ E. green portion of the spectrum.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Chlorophyll
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KfMC.03
GUIDELINE OBJECTIVE CODE: 31Kf
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: magnesium

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

The student should be able to identify the elements present in chlorophyll.

Item

Which of the following elements is a part of a chlorophyll molecule?

☐ A. calcium

☐ B. magnesium

☐ C. phosphorus

☐ D. iron

☐ E. manganese

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KfMC.04
GUIDELINE OBJECTIVE CODE: 31Kf
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: chlorophyll absorption spectrum graphical analysis

Guideline Objective

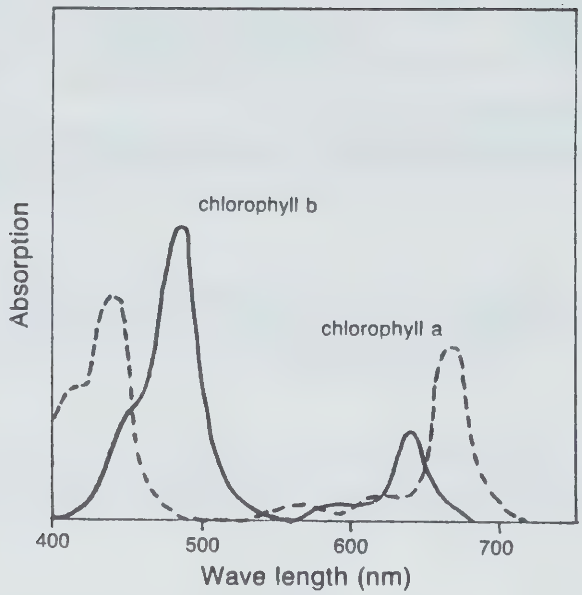
Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

The student should be able to identify the absorption spectrum of chlorophyll.

Item

Refer to Figure 3K.17.



This figure represents

- ☐ A. enzyme activity which occurs in chlorophyll *a* and chlorophyll *b*.
- ☐ B. the activity of chlorophyll *a* and *b* in varying light intensities.
- ☐ C. the range of activity resulting from photosystem I and II.
- ☐ D. the interaction of chlorophylls *a* and *b*.
- ☐ E. the absorption of varying qualities of light by chlorophylls *a* and *b*.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KfER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kf
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3, F.1, H.5, H.6
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: absorption spectrum chlorophyll graphical analysis

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

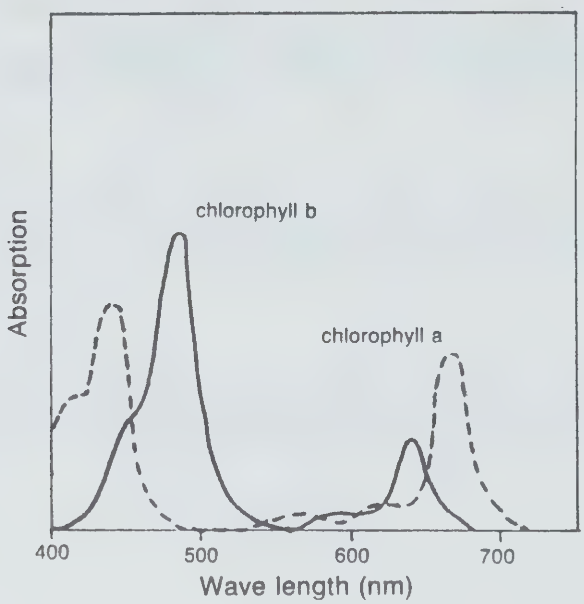
Item Focus

The student should be able to relate the absorption spectrum of chlorophyll and the graph of activity of photosynthesis to the actual occurrences of photosynthesis.

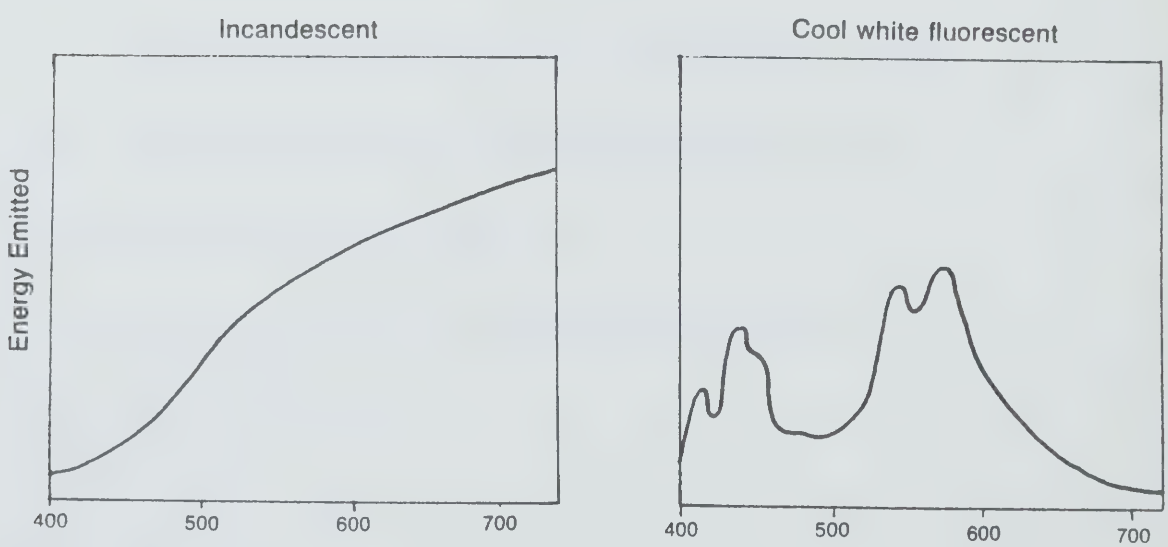
Item

Refer to Figures 3K.17 and 3K.19. How would you use the information provided in Figures 3K.17 and 3K.19 to your advantage as a consultant who gives advice to persons purchasing and growing plants under artificial light.

ABSORPTION SPECTRA OF CHLOROPHYLLS *a* AND *b*



EMISSION OF SPECTRA OF COMMON LAMPS



Response/Marking Scheme

Figure 3K.17 indicates those wavelengths of light which are being absorbed by plants for the process of photosynthesis. 2

Figure 3K.19 indicates those wavelengths that are produced by different light sources. 2

As a consultant, I would advise my clients to combine light from incandescent and fluorescent lamps for the plants to maintain a level of photosynthesis to remain healthy under artificial light. 2

Possible: 6

Maximum: 5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KfSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kf
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthetic pigments	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: pigment accessory (antennae) pigments

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

Same as above.

Item

A. Define the term pigment.
B. Name the pigment molecules most often found in the chloroplasts of the leaves of higher plants.
C. Which of the pigments are accessory (antennae) pigments? How is this term related to their function during photosynthesis?
D. What are the advantages to a plant of having several different pigments in its chloroplasts?

Response/Marking Scheme

A. Compounds which differentially absorb various wavelengths of light, and so appear coloured. 2

B. Chlorophyll *a, b, c, d* and the carotenoids. 2

C. Chlorophyll *b, c, d* and the carotenoids. 2

They absorb light energy and pass it on to chlorophll a. 1

D. Different pigments absorb different wavelengths of light most efficiently. 1

Thus, having a number of different pigments allows a plant to absorb light from a much wider range of the spectrum than if there were only one pigment. 1

At high light intensities, not all the energy can be utilized by the chlorophyll. Under these conditions oxygen molecules may be partly reduced, in which form they may destroy the chlorophyll molecules. The reduced oxygen molecules, however, bind readily to the carotene molecules, which prevents their destroying the chlorophyll. 2

Possible: 10

Maximum: 6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KfSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kf
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3, F.1, H.5
TOPIC: Photosynthesis	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: absorption spectrum chlorophyll graphical analysis

Guideline Objective

Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

The student should be able to relate the absorption spectrum of chlorophyll to its role in photosynthesis.

Item

Refer to Figure 3K.21.

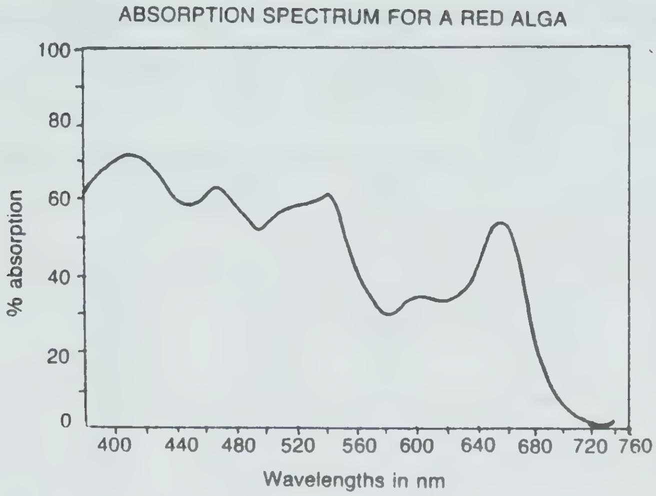


Figure 3K.21 represents the absorption spectrum of a red alga. An experiment was carried out to measure the photosynthetic activity of the alga at different wave lengths of light.

A. How would you expect the photosynthetic activity to correlate with the information provided in the graph?

B. The experiment yielded the following results:

WAVE LENGTH (nm)	% ACTIVITY
400	15
450	18
500	43
550	55
600	20
650	18
700	0
750	0

Graph these results, and interpret them.

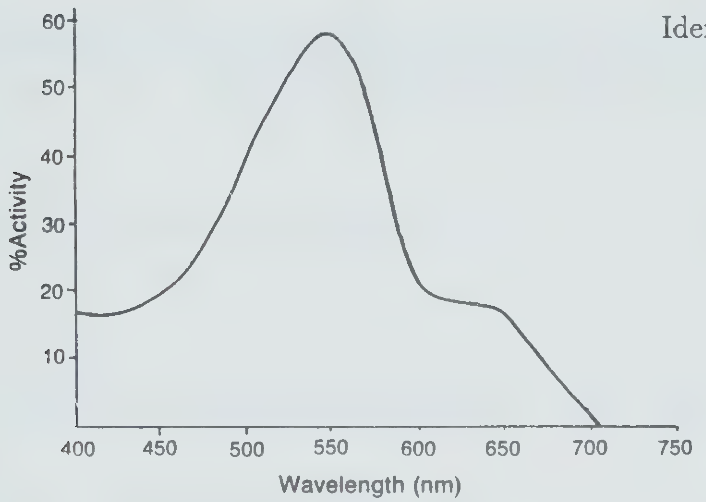
Response/Marking Scheme

A. Photosynthetic activity should correlate directly with the absorption spectrum. 1

Because maximum absorption should make the greatest amount of energy available for photosynthesis, this should result in the greatest photosynthetic activity 1

B. Title: Variation in Photosynthetic Activity at Different Wave Lengths 2

Axes: 1



Identification of Axes: 2

Curve: 1

The curve peaks at 550 nm where some light in the blue part of the spectrum promotes photosynthetic activity: this supports the expectations. 2

It was not expected that photosynthetic activity would be so low in the red (400 - 500 nm) range, nor in the violet range, where one would have expected a peak about 680 nm. 2

Possible: 12

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KfSA.03
GUIDELINE OBJECTIVE CODE: 31Kf
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: chlorophyll absorption spectrum graphical analysis

Guideline Objective

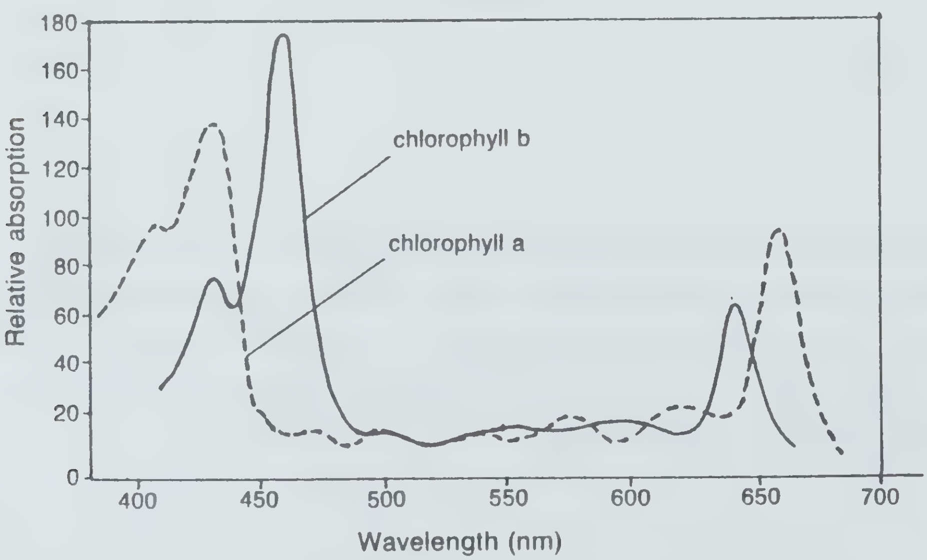
Students will be expected to explain the role of a photosynthetic pigment and compare the structure and absorption spectra of chlorophylls *a* and *b*.

Item Focus

The student should be able to relate the absorption spectrum of chlorophyll to its role in photosynthesis.

Item

Explain the significance of Figure 3K.16 and how it relates to photosynthesis.



Response/Marking Scheme

Figure 3K.16 is the absorption spectrum of chlorophylls	1
a and *b*, two photosynthetic molecules of light trapping pigments.	2
The graph represents the absorption of energy at the varying wavelengths of light.	1
This energy can then be utilized for the process of photosynthesis.	1
Possible:	5
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgMC.01
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: light reaction photophosphorylation

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the features of photophosphorylation.

Item

During photosynthesis, photophosphorylation refers specifically to the

☐ A. synthesis of ATP as a result of the movement of charged particles.

☐ B. reduction of NADP as a result of electron transport.

☐ C. synthesis of ATP as a result of photolysis.

☐ D. splitting apart of water as a result of light.

☐ E. synthesis of glucose as a result of the fixation of carbon.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photophosphorylation	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: photophosphorylation

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the source of energy for photophosphorylation.

Item

The ultimate source of energy for photophosphorylation is

☐ A. substrate level phosphorylation.

☐ B. light.

☐ C. oxidative phosphorylation.

☐ D. substrate level and oxidative phosphorylation.

☐ E. light and oxidative phosphorylation.

Response/Marking Scheme

Correct response: B

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photolysis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chlorophyll photosystem I photosystem II

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify photolysis in terms of its functions.

Item

During photosynthesis, the electrons released as a result of photolysis

- [ ] A. reduce chlorophyll molecules in photosystem II.
- [ ] B. oxidize a molecule of $NADP^+$.
- [ ] C. reduce the chlorophyll molecules in photosystem I.
- [ ] D. are directly involved in the fixation of carbon during the Calvin cycle.
- [ ] E. combine with hydrogen ions and oxygen to form water.

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
	DIFFICULTY LEVEL: L
TOPIC: Photophosphorylation	TIME ALLOCATION:
CURRICULAR EMPHASIS: Solid Foundations	

KEYWORDS: photolysis ATP

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the essential nature of photophosphorylation.

Item

During photosynthesis, photophosphorylation specifically refers to the

☐ A. synthesis of ATP as a result of electron transport.

☐ B. synthesis of reduced NAD as a result of electron transport.

☐ C. synthesis of ATP as a result of photolysis.

☐ D. splitting apart of water as a result of light.

☐ E. synthesis of glucose as a result of the fixation of carbon.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light reaction ATP

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the products of the light reaction.

Item

The essential outcome of the light reaction of photosynthesis is the

☐ A. synthesis of PGA and carbon dioxide.

☐ B. splitting of water and carbon dioxide.

☐ C. formation of ATP and absorption of carbon dioxide.

☐ D. formation of ATP and NADPH + H^+.

☐ E. breakdown of ATP and water.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light reaction chlorophyll

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the mechanism of energy transfer.

Item

The light energy that is absorbed by chlorophyll *a* is transfered as chemical energy to

☐ A. carotenoid pigments.

☐ B. a series of hydrogen acceptors.

☐ C. a series of chlorophylls.

☐ D. carbon dioxide.

☐ E. glucose.

Response/Marking Scheme

Correct response: B

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photophosphorylation
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgMC.07
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.5
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS:

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify aspects of chemiosmotic photophosphorylation.

Item

Which of the following is/are involved in oxidative photophosphorylation?

☐ A. the quantasomes

☐ B. the production of ATP

☐ C. the establishment of a hydrogen ion potential difference across the thylakoid membrane

☐ D. the presence of chlorophyll

☐ E. all of the above

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photolysis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgMC.08
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: photosynthesis

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify aspects of photolysis.

Item

The following are statements about the process of photolysis, as it relates to photosynthesis:

I It takes place during the 'light-independent' part of photosynthesis.
II It involves the chemical NADP.
III It occurs in the thylakoid of the chloroplast.
IV Oxygen gas is released in the process.
V It involves at least one carbon compound.

Which of the preceding five statements are correct?

☐ A. III and IV.

☐ B. I, II, III, IV and V.

☐ C. I and IV.

☐ D. III and V.

☐ E. II and V.

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.09
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, D.3
TOPIC: Photolysis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: Chlorella isotope

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the fact that oxygen is derived from water, not from carbon dioxide during photosynthesis (Kamen).

Item

During research on photosynthesis, Ruben, Kamen, and other scientists exposed the green alga, *Chlorella* to water which had been labelled with ^{18}O. (This non-radioactive isotope can be detected by a technique known as mass spectrometry). The experimental results revealed that ^{18}O was found in the gaseous product of photosynthesis but not in any carbohydrate product.

From the above information, it can be concluded that during photosynthesis

☐ A. water is the only possible source of oxygen gas.

☐ B. oxygen from water, ends up in the product starch.

☐ C. carbon dioxide is a possible source of oxygen gas.

☐ D. both water and carbon dioxide are sources of gaseous oxygen.

☐ E. carbon dioxide is a possible source of the oxygen in carbohydrates.

Response/Marking Scheme

Correct response: E

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photolysis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgMC.10
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: free oxygen chlorophyll

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the fact that oxygen is derived from water, and not from carbon dioxide in photosynthesis.

Item

During photosynthesis, the free oxygen released comes from

☐ A. carbon dioxide.

☐ B. water.

☐ C. glucose or starch.

☐ D. a five-carbon compound.

☐ E. chlorophyll.

Response/Marking Scheme

Correct answer: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgMC.11
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: ATP

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the important products of the light-dependent reaction.

Item

The light-dependent reaction of photosynthesis results in the

- [ ] A. production of ATP, carbon dioxide and reducing power.
- [ ] B. reduction of carbon dioxide and the release of oxygen.
- [ ] C. production of NADPH + H^+ and ATP.
- [ ] D. reduction of oxygen and the production of NADPH + H^+
- [ ] E. the fixation of carbon dioxide with the energy of ATP.

Response/Marking Scheme

Correct response: C

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.12
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photolysis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: free electrons

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify the role of water in photosynthesis.

Item

The role of water in photosynthesis is to

☐ A. provide energy.

☐ B. refract intense sunlight.

☐ C. activate chlorophyll.

☐ D. supply oxygen.

☐ E. supply free electrons.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMC.13
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photolysis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chlorophyll photosystem I photosystem II

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify photolysis in terms of its functions.

Item

During photosynthesis, the electrons released as a result of photolysis

- ☐ A. reduce chlorophyll molecules in photosystem II.
- ☐ B. oxidize a molecule of $NADP^+$.
- ☐ C. reduce the chlorophyll molecules in photosystem I.
- ☐ D. are directly involved in the fixation of carbon during the Calvin cycle.
- ☐ E. combine with hydrogen ions and oxygen to form water.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.7, A.10, D.3
TOPIC: Equation for Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: isotope

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and $NADPH + H^+$ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to discuss the significance of the equation for photosynthesis in the light of experimental evidence.

Item

Examine the following equation:

$$12H_2O^* + 6CO_2 \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2^* + 6H_2O$$

(O^* is a heavy isotope of oxygen)
Discuss the significance of the equation in establishing the presently accepted theory of photosynthesis. Explain why the former equation (below) is no longer accepted.

$$6H_2O + 6CO_2 \xrightarrow{\text{light}} C_6H_{12}O_6 + 6O_2$$

Response/Marking Scheme

The first equation supports the theory that the oxygen	1
given off during photosynthesis is derived from water	1
molecules. As water is broken down in photolysis, the	1
electrons from hydrogen atoms are used to replace the excited electrons removed from the chlorophyll. Molecules	1
of oxygen are released.	1
The former equation does not accurately show the role of the water molecules in photosynthesis.	1
Possible:	6
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: cyclic/non-cyclic photophosphorylation.

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to distinguish between cyclic and non-cyclic photophosphorylation.

Item

Distinguish between cyclic and non-cyclic photophosphorylation.

Response/Marking Scheme

Photophosphorylation refers to the action within the chloroplasts in the presence of light splitting a water molecule to obtain an excited electron and adding inorganic posphate to ADP to synthesize ATP.	2
CYCLIC: the excited electron from photosystem I	1
is returned to the photosystem by way of the cytochrome carrier system (Cytochrome b to cytochrome f),	2
generating ATP, but not reducing NADP.	1
NON-CYCLIC: both photosystems I and II are involved,	1
raising the excited electron to a higher energy level,	1
generating ATP as the electron moves through the cytochrome carrier system, and then	2
reducing NADP to NADPH + H^+.	1
Possible:	11
Maximum:	8

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.03R
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundation	TIME ALLOCATION:

KEYWORDS: thylakoid disc photophosphorylation photolysis chemiosmotic process.

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

Same as above.

Item

Refer to Figure 3K.23.

NON-CYCLIC ELECTON FLOW DURING THE LIGHT-DEPENDENT PHASE OF PHOTOSYNTHESIS

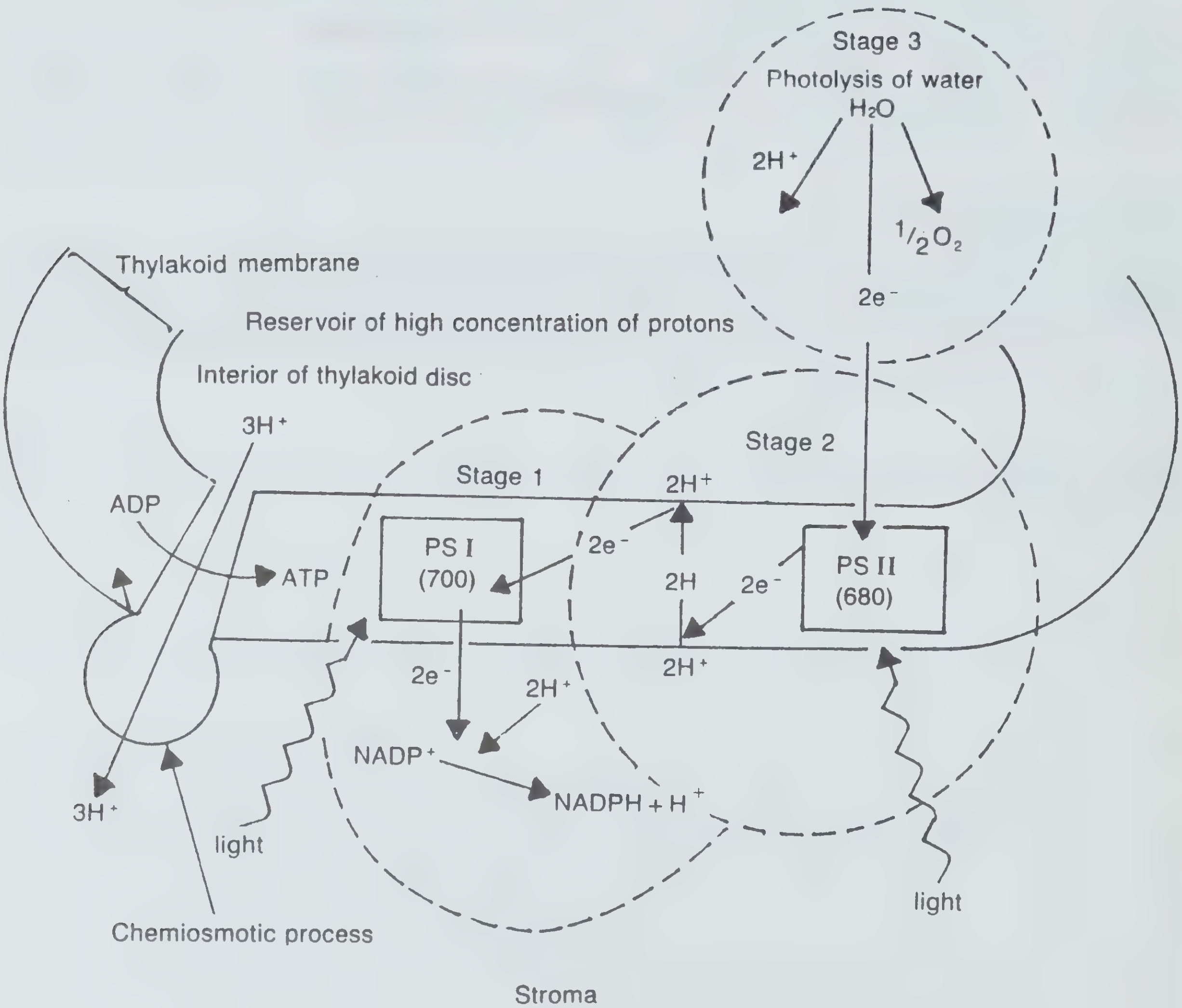


Figure 3K.23 illustrates non-cyclic electron flow during the light dependent stage of photosynthesis, together with the chemiosmotic process associated with the thylakoid membrane. Give a written explanation of the events illustrated in stage 1, stage 2, stage 3 and the chemiosmotic process.

Response/Marking Scheme

1st Stage:

Light absorbed by PS I (700) excites (raises the energy level) of electrons in the reaction centre of the chlorophyll *a* molecule. 2

In this excited state the chlorophyll molecule is readily oxidized by $NADP^+$. 1

The $NADP^+$ gains $2e^-$ from PS I and $2H^+$ from the stroma to form NADPH + H^+. 1

The NADPH goes to the light independent processes of photosynthesis. 1

2nd Stage:

Light energy absorbed by PS II (680) excites electrons in the reaction centre of the chlorophyll a molecule. 1

In this excited state the chlorophyll *a* gives up electrons to a carrier molecule in the membrane, this oxidizes the PS II chlorophyll. 1

The first carrier molecule can only carry hydrogen atoms (not electrons alone), thus the $2e^-$ combine with $2H^+$ from the stroma to form $2H^o$ atoms, which are 'carried ' across the membrane. 2

The energy of the electrons is used actively to transport the hydrogen ions across the membrane. 1

The 1st carrier molecule released the $2H^+$ into the interior of the thylakoid disc, building up a high concentration of H^+. 1

The $2e^-$ released from the $2H^o$ atoms reduce a second carrier molecule, which can only carry electrons. 1

The $2e^-$ finally reduce the PS I (700) chlorophyll molecule, which can then be reactivated by light energy and and subsequently oxidized again. 1

3rd Stage:

In the presence of the oxidized PS II (680) chlorophyll molecule, a powerful oxidizing enzyme splits water (photolysis). 1

There is an electron transfer to PS II, returning it to the reduced state. 1

The H^+'s from the water increases the concentration inside the thylakoid disc. 1

The oxygen is released as a waste product of the process. 1

The chemiosmotic process:

At specific ATP-ase enzyme sites on the membrane, hydrogen ions are allowed to pass across the membrane from the inside of the disc into the stroma. 1

This releases some of the potential difference established across the membrane by the fact that there is a higher concentration of hydrogen ions inside the membrane than there is in the stroma. 2

This energy powers the synthesis of ATP from ADP and a phosphate group (photophosphorylation). 1

The ATP is essential for the light independent reactions of photosynthesis. 1

Possible: 22

Maximum: 17

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg 21Kd
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.4, A.5, A.8, A.9
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:
KEYWORDS: Law of Conservation of Energy	First Law of Thermodynamics

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student will explain the mechanisms by which ATP and reducing power (NADPH + H^+) are produced in the light-dependent reaction, relating them to the Law of Conservation of Energy and the First Law of Thermodynamics.

Item

Explain the light-dependent reactions of photosynthesis in terms of the Law of Conservation of Energy and the First Law of Thermodynamics.

Response/Marking Scheme

Energy is neither created nor destroyed; it is only changed from one form to another.	2
Visible light energy from the sun is needed for the light-dependent reactions.	1
This energy, of wave lengths from about 450 nm to 700 nm, excites antenna molecules (chlorophyll) to raise electrons to a higher energy level, leaving the electrons susceptible to capture by molecules with a greater affinity for them.	2
This initiates a series of oxidation-reduction reactions, driving hydrogen ions (protons) across a thylakoid membrane and creating a potential difference (electrical charge).	3
Light energy is thus converted into electrical potential.	1
This potential energy is then converted into potential chemical energy at the CF_1 particle, stored in ATP.	2
Not all the energy originally trapped is converted into ATP or NADPH + H^+; some of it is converted into heat. Thus	1
less energy results from the process, yet no energy was destroyed.	1
ATP and NADPH + H^+ then provide energy for the light-independent reactions to form other products, such as glucose, that contain chemical potential energy.	1
These products are in turn used for cellular respiration releasing ATP to provide for the energy requirements of the cell and the organism.	1
Possible:	15
Maximum:	12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.05R
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.9
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundation	TIME ALLOCATION:

KEYWORDS: oxidation/reduction.

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

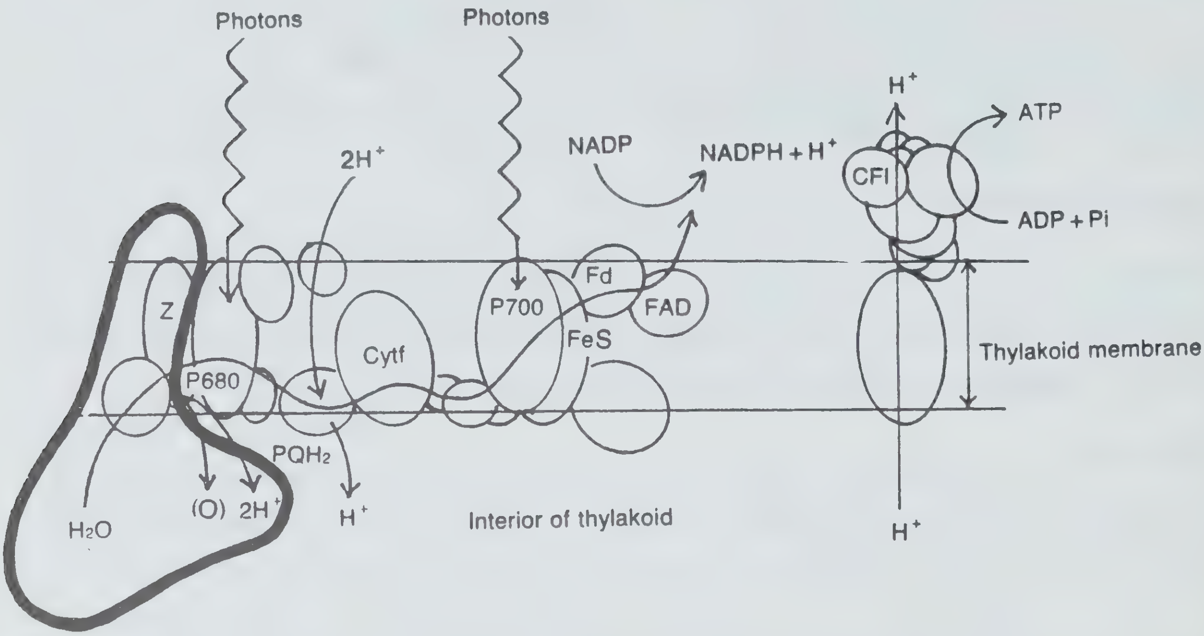
Item Focus

The student should be able to identify an oxidation-reduction reaction, and discuss the events that occur during the process.

Item

Refer to Figure 3K.24.

THE LIGHT-DEPENDENT REACTIONS OF PHOTOSYNTHESIS



Discuss the chemical reactions that occur within the outlined parts of the thylakoid membrane shown in Figure 3K.24 with respect to

A. the name of the types of reactions,
B. the events that occur during these reactions, and
C. the energy transfer involved.

Response/Marking Scheme

A. oxidation and reduction. 2

B. two electrons are removed from the hydrogen of water and transferred to the "Z" molecule in the thykaloid membrane. 2

The two hydrogen ions are then removed from the water into the loculus. 1

The water molecule has been oxidized, while the "Z" molecule has been reduced. 2

C. The energy necessary to remove electrons from water comes from the more oxidized "Z" molecule, which in turn results from the oxidation of chlorophyll *a* molecule in the first photoevent at P680. 2

Possible: 9

Maximum: 8

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.06R
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.9
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundation	TIME ALLOCATION:

KEYWORDS: oxidation/reduction

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

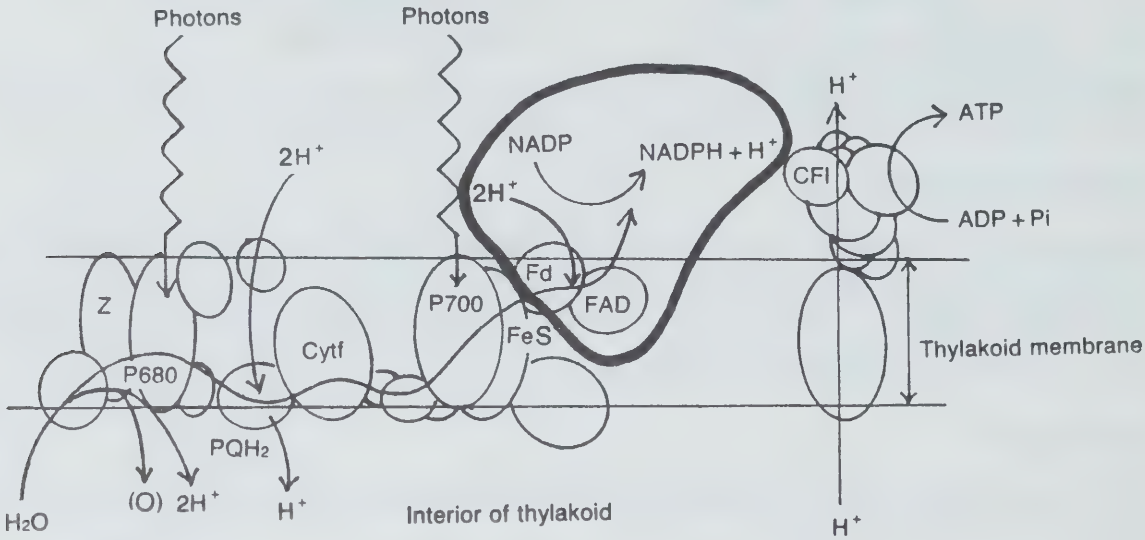
Item Focus

The student should be able to identify an oxidation-reduction reaction, and discuss the events that occur in such a reaction.

Item

Refer to figure 3K.25.

THE LIGHT-DEPENDENT REACTIONS OF PHOTOSYNTHESIS



With reference to the chemical reactions that are circled in Figure 3K.25,

A. name the types of reactions involved,
B. discuss the events that occur during these reactions,
C. describe the energy transfer involved.

Response/Marking Scheme

A. oxidation and reduction 2

B. Two electrons from the Fd molecule are transferred to FAD, reducing the FAD molecule. 1

Two hydrogen ions from outside the thylakoid membrane are transferred to FAD, thereby further reducing the FAD molecule to FADH + H^+ 1

Both electrons and both hydrogen ions gained in reduction are transferred to NADP, thereby reducing NADP to NADPH + H^+, and oxidizing FAD. 2

C. The energy from both photoevents 680 and 700 oxidize their respective antenna molecules enough to provide the energy necessary to force the electrons through the carrier molecules of the thylakoid membrane in a series of oxidation-reduction reactions. 2

Energy in the reduced NADPH + H^+ is used in the light independent reactions to form carbohydrates. 1

Possible: 9

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgER.07R
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.9
TOPIC: Light-Dependent Reactions	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Solid Foundation	TIME ALLOCATION:

KEYWORDS: oxidation/reduction

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

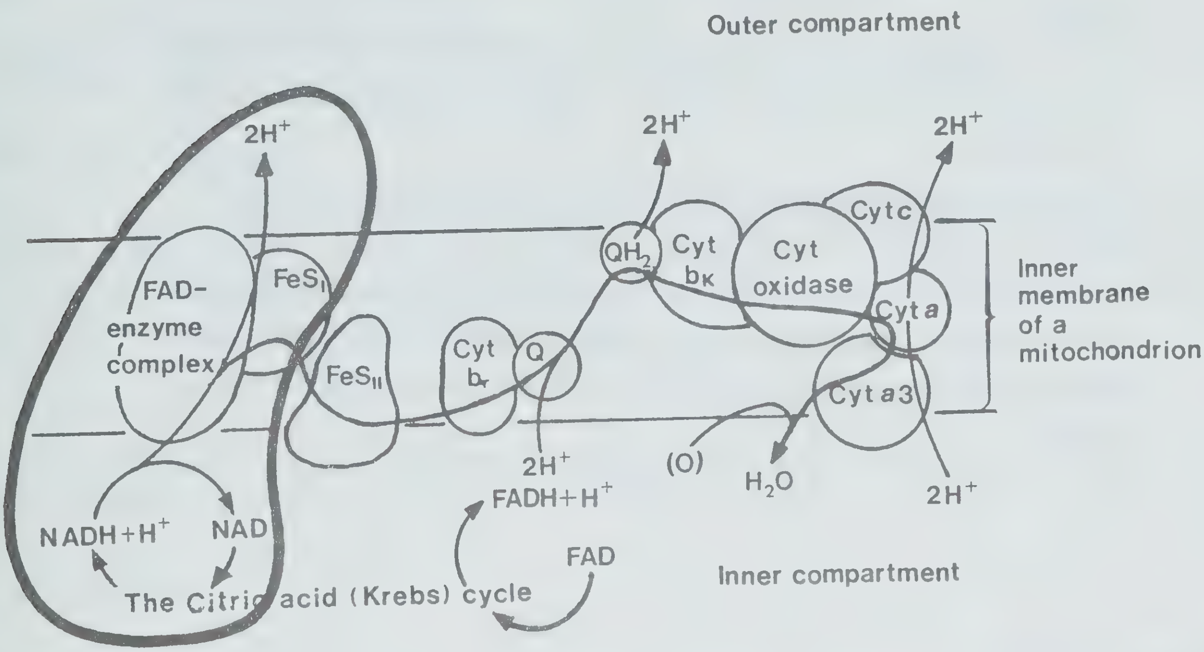
Item Focus

The student should be able to identify an oxidation-reduction reaction, and discuss events that occur in such a reaction.

Item

Refer to Figure 3K.26.

CHEMICAL REACTIONS WITHIN THE MITOCHONDRIAL CELL MEMBRANE



Discuss the chemical reactions that are circled in Figure 3K.26, a part of a mitochondrion, with respect to

A. the names of the types of reactions,
B. the events that occur during these reactions, and
C. the energy transfer involved.

Response/Marking Scheme

A. oxidation and reduction 2

B. $NADH + H^+$ is oxidized by the FAD-enzyme complex when two electrons and two hydrogen ions are removed, thereby reducing the FAD-enzyme complex. 2

The two hydrogen ions almost immediately are then lost from the FAD-enzyme complex and released into the outer crista compartment of the mitochondrion. 2

The two electrons gained by the FAD-enzyme complex are transferred to FeS_1. 1

C. The energy that drives the electron transport chain in these reactions is the result of molecules like the FAD-enzyme complex, that have a greater affinity for electrons than $NADH + H^+$, and are therefore good reducing agents. 2

Possible: 9

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Light-Dependent Reactions
CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B031KgER.08R
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, A.5, A.9
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: oxidation/reduction

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify an oxidation-reduction reaction and discuss the events that occur in such a reaction.

Item

Refer to Figure 3K.27.

CHEMICAL REACTIONS WITHIN THE MITOCHONDRIAL CELL MEMBRANE

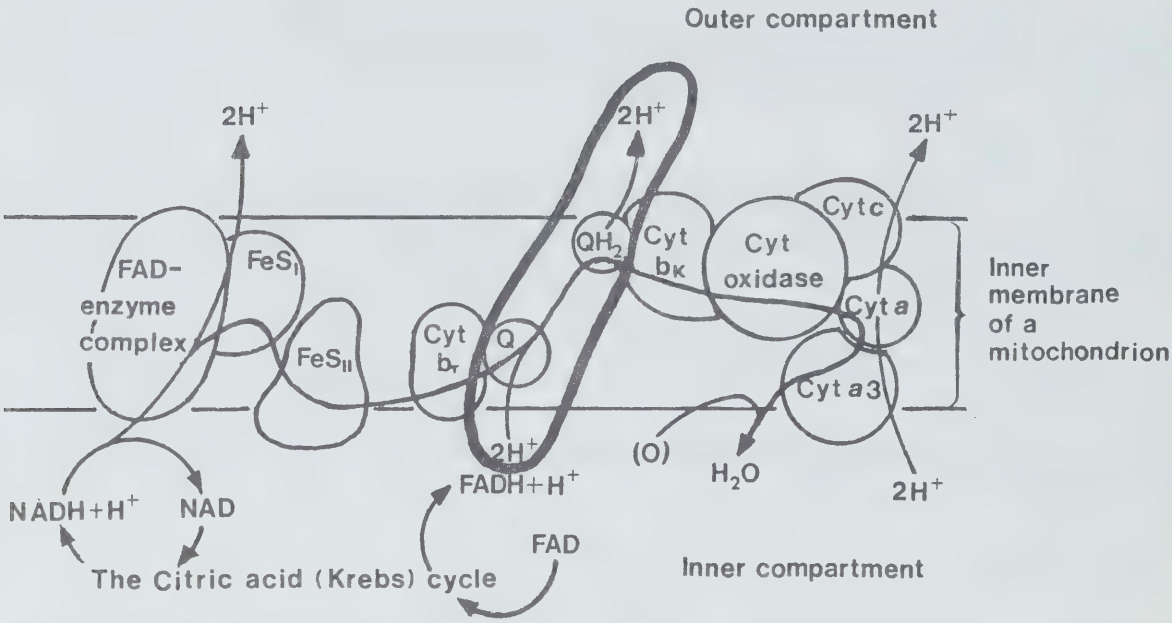


Figure 3K.27 shows a model of the cristal membrane of a mitochondrion. Discuss the chemical reactions that are circled in the diagram with respect to

A. the name of the types of reactions,
B. the events that occur during these reactions, and
C. the energy transfer that is involved.

Response/Marking Scheme

A. oxidation and reduction. 2

B. Molecule Q in the cristal membrane is reduced when two electrons from Cty b_T are transferred to it. 2

Molecule Q is further reduced by the addition of two hydrogen ions from the matrix. 1

Molecule Q travels across the membrane, and releases the two hydrogen ions to the outer compartment, and also transfers the two electrons to Cyt b_k, thereby becoming oxidized again. 2

C. The molecules that are more oxidized (Q, Cyt b_k) readily accept electrons and hydrogen ions. These electron and proton transfers provide the energy for the movement of molecule Q across the membrane. 2

Possible: 9

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgMA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: MA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: chemiosmotic phosphorylation photolysis carbon fixation

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify compounds associated with specific steps in the energy-trapping and carbon-fixing processes in photosynthesis.

Item

In photosynthesis, specific steps in the energy-trapping and carbon-fixing processes are associated with specific compounds. Select the appropriate letter from the column on the right and place it in the blank next to each correct substance in the column on the left.

____ 1. carbon dioxide	A. product of chemiosmotic phosphorylation
____ 2. NADPH + H^+	B. end product of electron transport reactions
____ 3. oxygen	C. product of photolysis
____ 4. ATP	D. product of carbon fixation cycle (Calvin Cycle)
____ 5. phosphoglyceraldehyde	E. raw material for carbon fixation cycle (Calvin Cycle)
____ 6. ADP	
____ 7. ribulose diphosphate	

Response/Marking Scheme

1:E, 2:B, 3:C, 4:A, 5:D, 6:D, 7:E

Maximum: 7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology

LEVEL: OAC

UNIT NUMBER: 03

UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

TOPIC: Light-Dependent Reactions

CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B031KgSA.01R

GUIDELINE OBJECTIVE CODE: 31Kg

INSTRUMENT TYPE: SA

KLOPFER: A.1, A.2, A.3, A.9

DIFFICULTY LEVEL: H

TIME ALLOCATION:

KEYWORDS: chlorophyll photolysis PS I PS II chemiosmotic phosphorylation

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to identify steps in the process of chemiosmotic phosphorylation, and explain “non-cyclic electron flow”.

Item

Refer to Figure 3K.28.

NON-CYCLIC ELECTRON FLOW DURING PHOTOSYNTHESIS

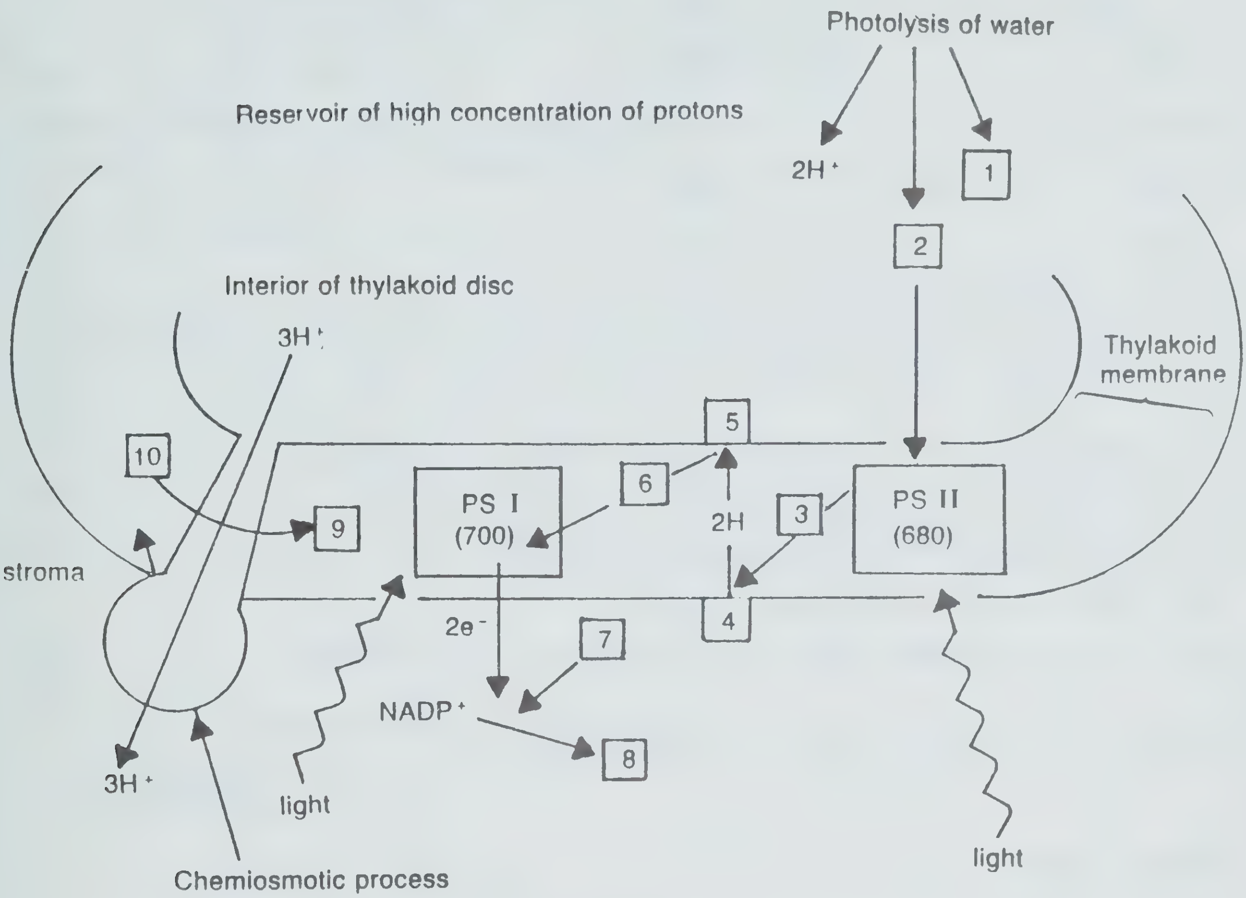


Figure 3K.28 illustrates non-cyclic electron flow during the light dependent stage of photosynthesis, together with the chemiosmotic process associated with the thylakoid membrane.

A. Write down, in symbolic form, the contents of the numbered squares.

1.	____________	6.	____________
2.	____________	7.	____________
3.	____________	8.	____________
4.	____________	9.	____________
5.	____________	10.	____________

B. Why is the electron flow in this system termed "non-cyclic"?

Response/Marking Scheme

A.

1. $1/2\ O_2$
2. $2e^-$
3. $2e^-$
4. $2H^+$
5. $2H^+$
6. $2e^-$
7. $2H^+$
8. $NADPH + H^+$
9. ATP
10. ADP

10

B. The electrons which leave the chlorophyll molecule of PS I move on to the light-independent phase of photosynthesis in the form of NADPH. 1

They do not return to PS I, and are thus non-cyclic. 1

The electrons from PS I are replaced from PS II, 1

which in turn are replaced from water, being released during photolysis. 1

Possible: 14

Maximum: 12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Cyclic Electron Flow
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KgSA.02
GUIDELINE OBJECTIVE CODE: 31Kg
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.9
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: PS I ATP thylakoid disc

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to describe cyclic electron flow and draw a diagram to represent it.

Item

Most of the light energy converted to chemical energy by the chlorophyll of PS I is transferred to NADPH and ATP by non-cyclic electron flow. Some of the energy, however, is utilized by <u>cyclic electron flow</u>.

1. Describe cyclic electron flow.

2. State the reason why it is termed 'cyclic'.

3. When does cyclic electron flow occur?

4. Draw a diagram to represent the process.

Response/Marking Scheme

1. When PS I is activated by light, it releases electrons to the same electron carriers as in non-cyclic flow. 2

   The electrons pass down the cytochrome carrier system, transporting hydrogen ions across the thylakoid membrane from the stroma to the inside of the disc. 2

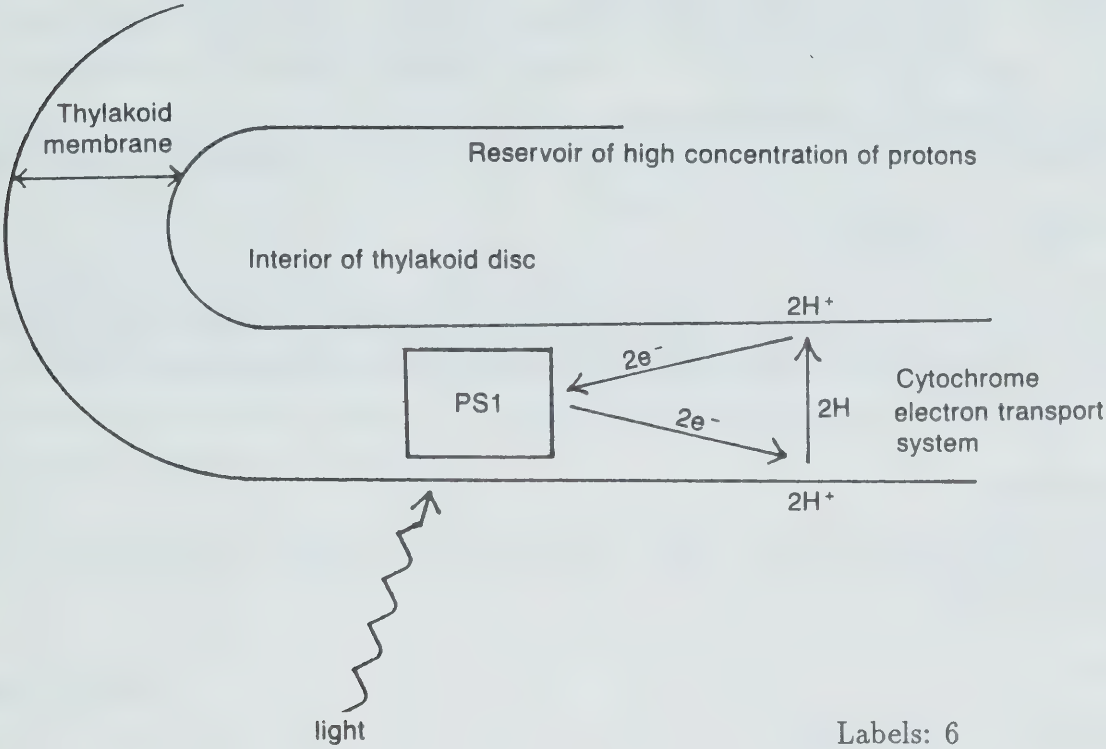
   This helps build up the reservoir of hydrogen ions inside the thylakoid disc, eventually to be used to generate ATP. 2

   The chlorophyll of PS I oxidizes the final electron carrier enzyme, gaining electrons to return to its reduced form. 2

   ATP is the only product of cyclic electron flow. 1
2. Termed 'cyclic' because the chlorophyll 700 of PS I serves as both the original electron donor and the final electron acceptor. 2
3. Cyclic electron flow is thought to occur when most of the $NADP^+$ has been reduced, leaving a shortage of electron acceptors, which leads to the acceptance of the electrons by the cytochrome electron carrier system. 3

4 Diagram to illustrate Cyclic Electron Flow. 2

CYCLIC ELECTRON FLOW



Labels: 6

Possible: 22

Maximum: 15

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgSA.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosystems I and II	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: reaction centre chlorophyll *a* thylakoid membranes photosystem

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to define “photosystem”, and explain the composition of photosystems I and II.

Item

In terms of photosynthesis:

A. What is a photosystem and where is it located?

B. Within each photosystem, there is said to be a “reaction centre”. What does a reaction centre consist of? What does it do?

C. There are two photosystems in the thylakoid membranes, photosystem I and photosystem II. Why are these names given? What do these photosystems consist of?

Response/Marking Scheme

A.	A photosystem is a cluster of light-absorbing pigment	2
	molecules. It is located in the thylakoid membrane of a chloroplast.	1
B.	A reaction centre consists of a chlorophyll *a* molecule to which the energy absorbed by the accessory pigments is passed,	2
	and, molecules which use this energy to start the first oxidation/reduction reactions of photosynthesis.	1
C.	PS I contains a form of chlorophyll *a* called P700 or pigment 700.	1
	It is given this name because the absorption peak of this molecule is in the longer red wavelength range of approximately 700 nm.	2
	PS II contains a form of chlorophyll *a* called P680 or pigment 680	1
	because the absorption peak of this molecule is in the shorter red wavelength range of approximately 680 nm.	2

Possible: 12

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgSA.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light-dependent reactions

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to state the importance of each of the requirements of photosynthesis to the process.

Item

State the role of each of the following substances to the process of photosynthesis:

A. water

B. $NADP^+$

C. chlorophyll

D. cytochromes

Response/Marking Scheme

A. Water is the source of electrons and hydrogen for the oxidized chlorophyll molecule. 2

B. $NADP^+$ serves as the terminal acceptor for electrons and hydrogen that passes through the light reaction. 2

C. Chlorophyll molecules, when struck by a photon of light, release an electron at an excited (high energy) state, becoming oxidized. 2

D. Cytochromes serve as carrier molecules for electrons in the photosynthetic electron transport system. 2

Possible: 8

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgSA.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.9
TOPIC: Cyclic Electron Flow	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Communication	TIME ALLOCATION:

KEYWORDS: PS I ATP thylakoid disc

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

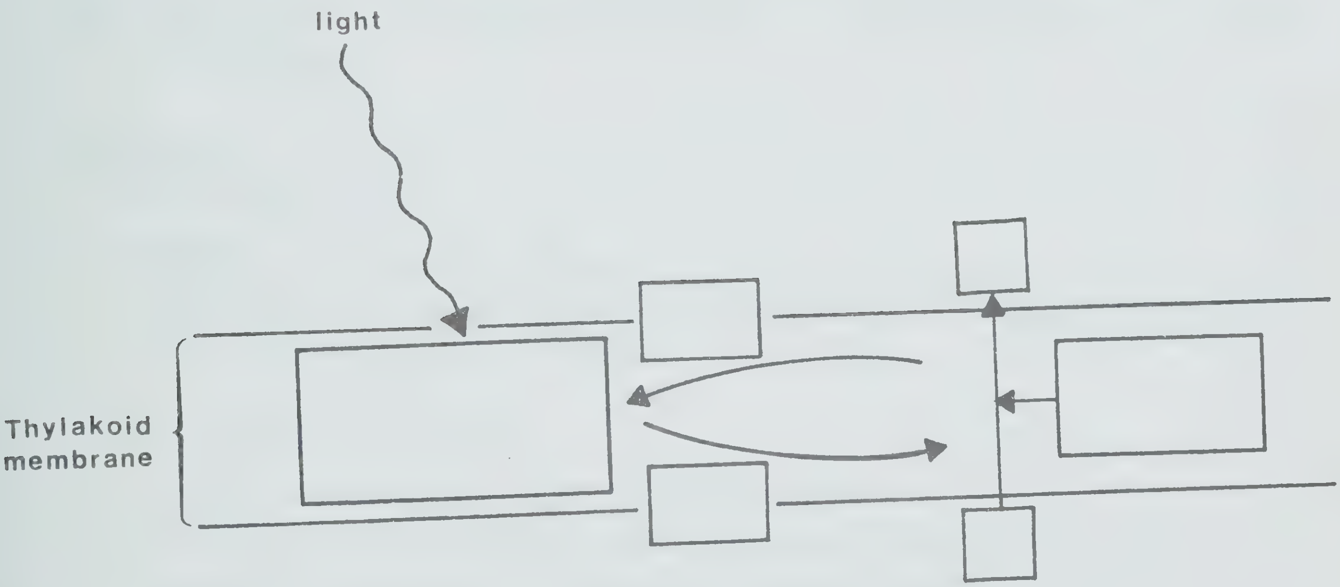
The student should be able to describe cyclic electron flow and draw a diagram to represent it.

Item

Most of the light energy converted to chemical energy by the chlorophyll of PS I is transferred to NADPH and ATP by non-cyclic electron flow. Some of the energy, however, is utilized by cyclic electron flow.

1. State the reason why the process is termed 'cyclic'.
2. Describe cyclic electron flow.
3. What are the product(s) of cyclic electron flow?
4. Complete the following diagram to represent the process.

CYCLIC ELECTRON FLOW



Response/Marking Scheme

1. Termed 'cyclic' because the chlorophyll 700 of PS I serves as both the original electron donor and the final electron acceptor. 2
2. When PS I is activated by light, it releases electrons to the same electron carriers as in non-cyclic flow. 2

The electrons pass down the cytochrome carrier system, transporting hydrogen ions across the thylakoid membrane from the stroma to the inside of the disc. 2

This helps build up the reservoir of hydrogen ions inside the thylakoid disc, eventually to be used to generate ATP. 2

The chlorophyll of PS I oxidizes the final electron carrier enzyme, gaining electrons to return to its reduced form. 2

3. ATP is the only product of cyclic electron flow. 1
4. Diagram to illustrate Cyclic Electron Flow.

Labels: 6

Possible: 15

Maximum: 10

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KgSA.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kg
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Photosystems I and II	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: reaction centre chlorophyll *a* thylakoid membranes photosystem

Guideline Objective

Students will be expected to, in terms of photosystems I and II and the chemiosmotic theory of ATP synthesis, describe how light energy is converted into the chemical potential energy of ATP and NADPH + H^+ (reduced nicotinamide adenine dinucleotide phosphate) during the light-dependent reactions of photosynthesis.

Item Focus

The student should be able to define "photosystem", and explain the composition of photosystems I and II.

Item

In terms of photosynthesis:

A. What is a photosystem and where is it located?
B. Within each photosystem, there is said to be a "reaction centre". What does a reaction centre consist of and what does it do?

Response/Marking Scheme

A. A photosystem is a cluster of light-absorbing pigment — 1
molecules. It is located in the thylakoid membrane of a chloroplast. — 2

B. A reaction centre consists of a chlorophyll *a* molecule to which the energy absorbed by the accessory pigments is passed, — 2
and, molecules which use this energy to start the first oxidation/reduction reactions of photosynthesis. — 1

Possible: 6

Maximum: 5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, D.3
TOPIC: Carbon Fixation	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: Chlorella isotope

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to account for the fact that oxygen derived from carbon dioxide becomes incorporated into carbohydrates during photosynthesis (Kamen).

Item

During research on photosynthesis,Ruben, Kamen, and other scientists exposed the green alga, *Chlorella*, to carbon dioxide which contained the non-radioactive isotope of oxygen, ^{18}O. The results revealed that the ^{18}O appeared in a carbohydrate product but <u>not</u> in the oxygen released. During photosynthesis, from the above data, it can be concluded that

☐ A. carbon dioxide is the source of the oxygen gas.

☐ B. water is the source of the oxygen gas.

☐ C. both water and carbon dioxide are sources of gaseous oxygen.

☐ D. oxygen from carbon dioxide becomes incorporated into a carbohydrate product.

☐ E. none of the above conclusions can be drawn due to insufficient data.

Response/Marking Scheme

Correct response: D

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KhMC.02
GUIDELINE OBJECTIVE CODE: 31Kh
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: ribulose diphosphate

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify the substance that carbon dioxide combines with in the dark reaction.

Item

During photosynthesis, carbon dioxide combines with

☐ A. NAD^+

☐ B. $NADP^+$

☐ C. ribulose

☐ D. ribulose diphosphate

☐ E. PGA

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ribulose diphosphate

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify carbon reduction steps of the light-independent reaction.

Item

In chloroplasts, in the presence of ATP and reduced NADP, ribulose diphosphate is converted to PGA molecules after the addition of

☐ A. oxygen and glucose.

☐ B. oxygen and PGAL.

☐ C. carbon dioxide and water.

☐ D. PGAL and carbon dioxide.

☐ E. oxygen.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Carbon Fixation
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KhMC.04
GUIDELINE OBJECTIVE CODE: 31Kh
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: phosphoglyceraldehyde (PGAL)

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify the formation of phosphoglyceraldehyde as a product of carbon fixation.

Item

Which of the following is a product of the carbon fixation (assimilation) stage of photosynthesis?

☐ A. oxygen.

☐ B. carbon dioxide.

☐ C. the reduced form of NADP.

☐ D. phosphoglyceraldehyde (PGAL).

☐ E. ATP.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Calvin Cycle	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phosphoglyceric acid (PGA)

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify the first organic compound to be formed in the Calvin cycle.

Item

After carbon dioxide from the atmosphere has been fixed in photosynthesis, the first organic compound to be formed in the Calvin (C_3) cycle is

☐ A. 3-phosphophoglyceric acid (PGA).

☐ B. ribulose diphosphate (RDP).

☐ C. glucose.

☐ D. 3-phosphophoglyceraldehyde (PGAL).

☐ E. oxaloacetic acid (OAA).

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhMC.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Calvin Cycle	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: energy

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify the source of energy for the fixation of carbon dioxide in the Calvin cycle.

Item

In the Calvin (C_3) cycle of the light-independent ("dark") reactions of photosynthesis, the immediate source of energy for the fixing of carbon dioxide is

☐ A. light.

☐ B. photolysis.

☐ C. water molecules.

☐ D. hydrogen ions.

☐ E. ATP.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Light and Dark Reactions	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ATP carbon dioxide NADPH + H^+ Calvin (C_3) cycle

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

Same as above.

Item

Discuss briefly, the role played in the Calvin (C_3) cycle by

A. carbon dioxide
B. ATP
C. NADPH + H^+

Response/Marking Scheme

A. Carbon dioxide acts as the source of carbon atoms	1
for the carbohydrate synthesized in the Calvin cycle.	1
B. ATP provides energy	1
to link carbon atoms in a chain.	1
C. NADPH + H^+ provides electrons and hydrogen atoms	2
to reduce the carbon dioxide.	1
Possible:	8
Maximum:	6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Light and Dark Reactions	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ATP NADPH + H^+ Calvin (C_3) cycle

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

Same as above.

Item

Compare the roles of ATP and NADPH in the Calvin cycle.

Response/Marking Scheme

Both compounds provide energy.	1
NADPH + H^+ is used in oxidation reduction reactions	1
to store energy in C–H or O–H bonds,	1
while ATP is used in non-redox reactions	1
storing energy in C–C bonds.	1
Possible:	5
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: light-dependent reaction light-independent reaction

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to describe the relationships between the photochemical and carbon-fixing stages of photosynthesis.

Item

Describe the relationship between the photochemical (light-dependent) and carbon-fixing (light-independent) stages of photosynthesis.

Response/Marking Scheme

The photochemical reaction of photosynthesis fixes the energy of light into	1
energy-rich transfer molecules (ATP and NADPH + H^+)	2
These are required by the light-independent reaction	1
to produce the phosphoglyceraldehyde.	1
Possible:	5
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhER.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.11.
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ATP NADPH

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to describe the energy relationships of the photosynthesis equations.

Item

In the overall equation for photosynthesis, energy-rich transfer molecules (ATP, NADPH + H^+) do not appear as a reactant or product, yet they appear in both the equations for the light-dependent and light-independent reactions. Explain why this is so.

Response/Marking Scheme

The energy-rich transfer molecules produced by the light-	1
dependent reaction are utilized by the	1
light-independent reaction. Because of this, the net energy increase shows in	
the products: energy-rich carbohydrates	1
from the low-energy compounds, carbon dioxide and water.	1
Possible:	4
Maximum:	4

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.11
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phosphoglyceraldehyde (PGAL) light-independent reaction.

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to write balanced word equations to illustrate the production of ATP, NADPH + H^+ and PGAL.

Item

In the form of equations, illustrate how ATP and NADPH + H^+ are produced by the light-dependent reaction of photosynthesis, and how they are used to produce phosphoglyceradehyde (PGAL).

Response/Marking Scheme

$$2(3-\mathrm{PGA})+2\mathrm{ATP} \overset{\mathrm{Mg}^{++}}{\rightleftharpoons} 2(1,3-\mathrm{PGA})+2\mathrm{ADP} \qquad 4$$

$$2(1,3-\mathrm{PGA})+2(\mathrm{NADPH}+\mathrm{H}^{+}) \rightleftharpoons 2(3-\mathrm{PGAL})+2\mathrm{NADP}^{+} \qquad 4$$

Possible: 8

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KhSA.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kh
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.11
TOPIC: Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: PGA PGAL

Guideline Objective

Students will be expected to describe how the ATP and NADPH + H^+ from the light-dependent reactions are used to fix carbon and produce phosphoglyceraldehyde (PGAL) in the Calvin (C_3) cycle.

Item Focus

The student should be able to identify processes and reactants associated with equations for photosynthesis.

Item

$$2(3-\mathrm{PGA}) + 2\underline{\mathrm{ATP}} \overset{\mathrm{Mg}^{++}}{\rightleftharpoons} 2(1,3-\mathrm{PGA}) + 2\mathrm{ADP}$$

$$2(1,3-\mathrm{PGA}) + 2(\underline{\mathrm{NADPH} + \mathrm{H}}^{+}) \rightleftharpoons 2(3-\mathrm{PGAL}) + 2\mathrm{NADP}^{+}$$

A. In which biological process would these reactions occur?

B. State the immediate source of each of the underlined reactants.

Response/Marking Scheme

A. Light-independent reaction of photosynthesis. 1

B. Both ATP and NADPH + H^+ are produced by the light-dependent reaction of photosynthesis. 2

Possible: 3

Maximum: 3

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2
TOPIC: Products of Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phosphoglyceraldehyde glucose

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to identify substances produced directly from phosphoglyceraldehyde.

Item

Which one of the following is <u>NOT</u> produced directly from phosphoglyceraldehyde (PGAL)?

☐ A. fructose

☐ B. glucose

☐ C. ribose

☐ D. ribulose

☐ E. glyceric acid

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Aerobic Respiration	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS:

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to identify the end products of aerobic respiration in green plants.

Item

The end products of aerobic respiration in green plants are

☐ A. oxygen and water.

☐ B. nitrogen and oxygen.

☐ C. carbon dioxide and water.

☐ D. hydrogen and oxygen.

☐ E. nitrogen and carbon dioxide.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Cellular Respiration	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: aerobic respiration

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to investigate the relationship between photosynthesis and respiration.

Item

Respiration in green plants takes place

☐ A. only when photosynthesis stops.

☐ B. only in the cells which do not contain chlorophyll.

☐ C. all of the time.

☐ D. only during the night time.

☐ E. only during the day time.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiMC.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, C.2.
TOPIC: Products of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: alkaloids

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to identify a selective advantage to the plant of the synthesis of molecules with pharmaceutical properties.

Item

Many plants store, in their leaves, complex organic molecules (such as caffeine, cocaine and nicotine) that have pharmaceutical uses. A possible advantage to the plant would be that these products

☐ A. prevent the leaves from freezing in winter.

☐ B. attract pollinators to the plant.

☐ C. are waste products, excreted when the leaves are shed.

☐ D. increase the efficiency of light absorption.

☐ E. deter herbivores from eating the leaves.

Response/Marking Scheme

Correct response: E

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis/Respiration
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KiER.01
GUIDELINE OBJECTIVE CODE: 31Ki
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, I.1
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS:

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch, and other products.

Item Focus

The student will account for the interrrelationship of photosynthesis and aerobic respiration.

Item

Consider the following statement:

"Green leaves photosynthesize during daylight and respire at night."

Comment on the correctness of the statement. Explain the relationship between the two processes.

Response/Marking Scheme

The statement is, in fact, correct.	1
The implication that respiration occurs only at night is incorrect.	1
Respiration is an essential, continuing process in a leaf, both day and night.	2
Photosynthesis, since it requires light energy, occurs only during the day.	2
During the day, the rate of photosynthesis exceeds that of respiration, thus determining the exchange of gases between the leaf and the air surrounding it.	1
Consequently, all the carbon dioxide produced by respiration during the day is used up by photosynthesis, plus the additional amount that diffuses in through the stomata.	2
Also, respiration does not use all the oxygen produced in photosynthesis. The excess oxygen diffuses out through the stomata into the air, supplying the oxygen that animals consume in respiration.	2
In the dark, since photosynthesis stops, respiration determines the exchange of gases.	1
Consequently, at night, oxygen diffuses into the leaf, and carbon dioxide diffuses out.	1
Possible:	13
Maximum:	8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Electron Transport	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: ATP aerobic respiration

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to explain the process of energy release in the electron transport chains of photosynthesis and aerobic respiration.

Item

"Life can be said to be fundamentally a matter of the transport of electrons between energy levels." Support this statement with specific references to the processes of photosynthesis and cellular respiration. Include examples of electron carriers.

Response/Marking Scheme

The statement is true in that organisms must have a continuous supply of energy to stay alive. This energy	1
comes from the electron transport chain in the form of ATP.	1
The phosphate bond of ATP carries energy in the bond that links ADP and P_i.	1
This bond is formed as electrons are passed from one carrier to the next in the chain,	1
by the oxidation/reduction of adjacent carrier molecules.	1
In photosynthesis, there are carriers in both the cyclic and non-cyclic pathway. Accept examples such as ferrodoxin and plastoquinone.	2
In aerobic respiration, in the mitochondria, electrons	1
are passed in oxidative phosphorylation from NADH	1
to flavoproteins (iron-sulphur proteins)to	1
cytochromes b_1, c_2, c, and ($a + a_3$)	1
to ubiquinone (Q) that carries hydrogen ions across the membrane.	1
Possible:	12
Maximum:	10

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KiER.03
GUIDELINE OBJECTIVE CODE: 31Ki
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, C.1, C.2, D.2
DIFFICULTY LEVEL: H
TIME ALLOCATION:

KEYWORDS: oxygen sulphur bacteria

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch, and other products.

Item Focus

The student should be able to account for the source of the oxygen released during photosynthesis.

Item

Although the net equation for photosynthesis is sometimes represented as

$$H_2O + CO_2 \longrightarrow (CH_2O) + O_2$$

another equation often used is

$$2H_2O + CO_2 \longrightarrow (CH_2O) + O_2 + H_2O$$

A. Which equation is the better representation and why?

B. Green sulphur bacteria also assimilate carbon dioxide in the presence of hydrogen sulphide (H_2S), producing molecular sulphur (S_8). How does this information support either of the above equations? Write an equation to represent the synthesis by sulphur bacteria.

Response/Marking Scheme

A. Although both equations represent aspects of the net equation for photosynthesis correctly, 1

the second is preferable in that it shows 1

that water is produced during photosynthesis. 1

B. The synthesis by the sulphur bacteria supports the second equation, since the reactants and products more closely resemble it than the first: 1

$$8H_2S + 4CO_2 \longrightarrow 4(CH_2O) + S_8 + 4H_2O \qquad 2$$

Possible: 6

Maximum: 5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiER.04
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, C.1, C.2, C.4, D.2
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: oxygen

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch, and other products.

Item Focus

The student should be able to account for the source of oxygen released during photosynthesis.

Item

The net equation for photosynthesis is often represented as

$$6H_2O + 6CO_2 \longrightarrow C_6H_{12}O_6 + 6O_2$$

This equation may lead to a misrepresentation about the source of the oxygen released. Discuss briefly this possible misrepresentation, and how one might establish the actual source of the oxygen.

Response/Marking Scheme

The misconception is that the oxygen may be derived from the carbon dioxide used in carbon fixation.	1
In fact, the oxygen comes from the water molecule that	1
supplies hydrogen atoms and excited electrons in the	1
light dependent reaction.	1
To establish the source of the oxygen, radioactively labelled oxygen could be supplied in water made available	1
for photosynthesis. After the process, it could be determined that this oxygen was released as gas	1
and not incorporated into carbohydrates.	1
Possible:	7
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiLA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5, A.10, A.11, D.1, D.2, D.3, D.6
TOPIC: Photosynthesis/Respiration	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: compensation point graphical analysis

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student will account for the interrelationship of photosynthesis and aerobic respiration.

Item

The following results were obtained from an experiment with a water plant. A manometer was set up to measure the oxygen interchange between the plant and its environment at different levels of light intensity. A negative number shows that the plant was absorbing oxygen; a positive number indicates that the plant was releasing oxygen.

LIGHT INTENSITY klx	OXYGEN UPTAKE(-) OR RELEASE(+) mL/g (fresh mass)/h
0	-15
5	-8
10	+5
20	+25
50	+65
100	+125
150	+155

A. Graph the data obtained.

B. Explain the significance of the curve in terms of the processes going on in the cells of the plant.

Response/Marking Scheme

A.	Title for the graph.	1
	Axes correctly oriented and labelled.	1
	Scale is proportioned to the page.	1
	Correct curve, units indicated.	2
B.	Significance:	
	The graph originates at zero light intensity, with an uptake of oxygen. The reason is that without light, the plant is using oxygen for cellular respiration.	2
	As the light intensity increases, photosynthesis begins, producing some oxygen, at first not enough to compensate for the amount required for respiration.	2
	Between 5 and 10 klx, the curve crosses the X axis, reaching the compensation point where the gases produced by respiration and photosynthesis exactly balance, and there is no net exchange with the environment.	2
	Above the compensation point, there is a net release of oxygen, since photosynthesis now exceeds respiration. The release of oxygen continues to increase as the light intensity increases.	2
	Eventually the curve starts to level off as some factor other than light intensity becomes limiting. The rate of photosynthesis has now reached a maximum for the conditions affecting the plant.	2
	Possible:	16
	Maximum:	12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KiSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Ki
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, I.3
TOPIC: Photosynthesis/Respiration	DIFFICULTY LEVEL: `L
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: oxygen carbon dioxide

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student will account for the interrelationship of photosynthesis and aerobic respiration.

Item

"Plants instead of affecting the air in the same manner as with animal respiration, reverse the effects of breathing and tend to keep the atmosphere sweet and wholesome."

- Joseph Priestley, 1772.

Comment on the processes underlying Priestley's observation.

Response/Marking Scheme

Priestley was correct in observing that photosynthesis is in effect the reverse of aerobic respiration, since	1
their net equations are the opposite of one another.	1
The product of respiration, carbon dioxide, is the raw material of photosynthesis.	2
The product of photosynthesis, oxygen, is what Priestley speaks of "sweetening" the atmosphere, making it capable of supporting aerobic respiration once again.	2
Possible:	6
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis/Respiration
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KiSA.02
GUIDELINE OBJECTIVE CODE: 31Ki
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.5, A.9
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: light-dependent reaction oxidative phosphorylation.

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism, describe how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

The student should be able to compare the light-dependent reaction of photosynthesis with oxidative phosphorylation.

Item

Complete the following chart, comparing and contrasting the light-dependent reactions of photosynthesis with the oxidative phosphorylation reactions of cellular respiration.

	PHOTOSYNTHESIS	CELLULAR RESPIRATION
ORGANELLE		
LOCATION WITHIN ORGANELLE		
REACTANT(S)		
ACTIVITY		
ENERGY SOURCE		
END RESULT		
END PRODUCTS		

Response/Marking Scheme

	PHOTOSYNTHESIS	CELLULAR RESPIRATION
ORGANELLE	chloroplast	mitochondrion
LOCATION WITHIN ORGANELLE	thylakoid membrane	crista membrane
REACTANTS	water	NADH + H^+
ACTIVITY	electron transfer through the membrane via membrane proteins and hydrogen ion transport into the loculus of the thylakoid	electron transfer through the membrane via membrane proteins and hydrogen ion transport into the outer compartment of the mitochondrion
ENERGY SOURCE	light	reduced NADH + H^+
END RESULT	proton differential and thus an electrical potential difference more positive inside the thylakoid	proton differential and thus an electrical potential difference more positive inside the crista
END PRODUCTS	NADPH + H^+ and ATP	water and ATP

Marks: 2 For Each Comparison $\times$ 7 = 14

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Conditions Affecting Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KiSA.03
GUIDELINE OBJECTIVE CODE: 31Ki
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: photosynthesis aerobic respiration graphical analysis

Guideline Objective

Students will be expected to, including appropriate comparisons to aerobic catabolism describe, how PGAL can be used to produce glucose, sucrose, starch and other products.

Item Focus

Same as above.

Item

Refer to Figure 3K.32.

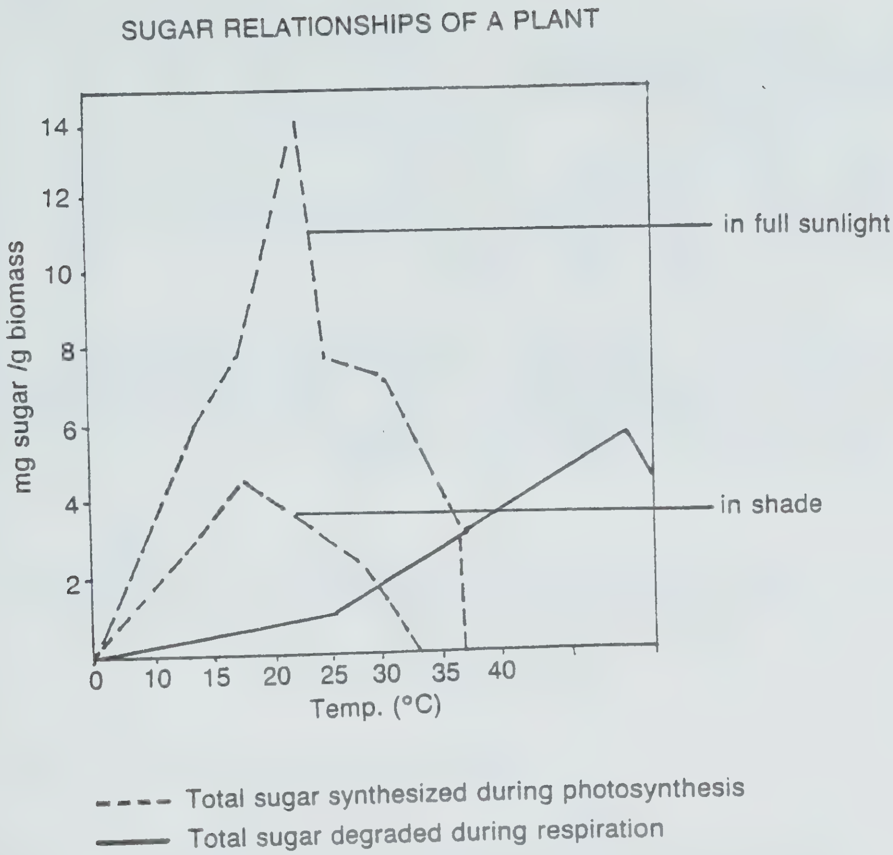


Figure 3K.32 shows the sugar relationships of a plant under different conditions of light. If a plant is placed in light of the intensity of full sunlight at 25°C for 48h, what will be the net effect on its sugar content? Explain your answer.

Response/Marking Scheme

The plant will increase in sugar content	1
because of the fact that it is synthesizing sugar	2
at a faster rate than it is degrading sugar for metabolic processes.	1
Possible:	4
Maximum:	4

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.10, A.11
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: limiting factor light intensity graphical analysis

Guideline Objective

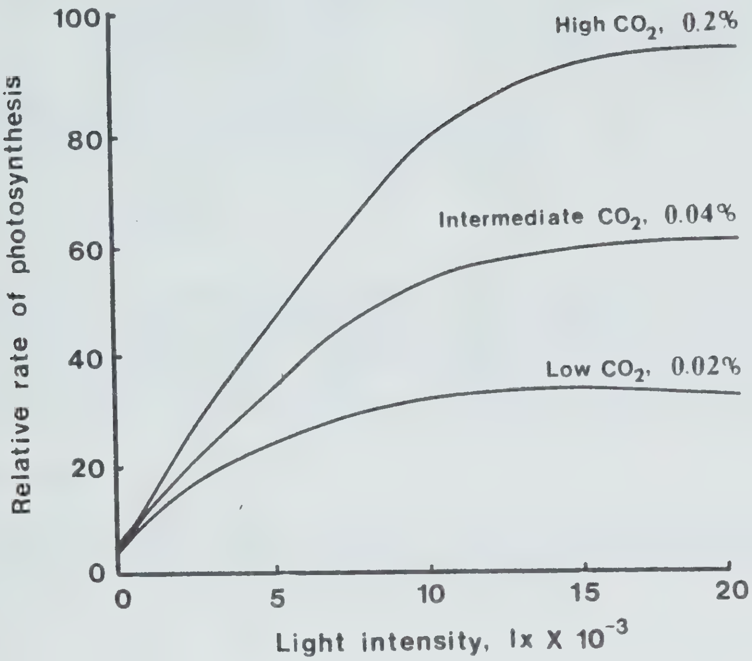
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student will be able to identify factors that affect the rate of photosynthesis from a graph.

Item

Refer to Figure 3K.29.



The following statements relate to Figure 3K.29:

I The greater the light intensity, the higher the rate of photosynthesis.
II The rate of photosynthesis increases as the light increases up to about 7×10^{-3} lx.
III Some other factor becomes limiting when the light intensity reaches 7×10^{-3} lx.
IV The higher the carbon dioxide concentration, the higher the rate of photosynthesis.
V Light is not the limiting factor on the rate of photosynthesis in Figure 3K.29

Which of the above statements can be verified using the data in Figure 3K.29?

☐ A. II, IV and V only.

☐ B. III, IV and V only

☐ C. I, I, and III only.

☐ D. II, III and V only.

☐ E. I, II, III, IV, and V.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: limiting factor graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

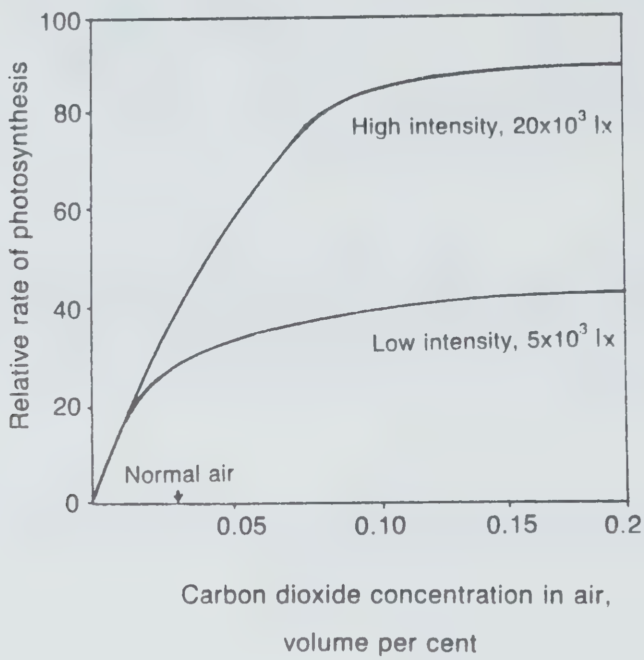
Item Focus

The student should be able to describe how the rate of photosynthesis is affected by CO_2 concentration, based on evidence from experiments.

Item

Refer to Figure 3K.30.

RATE OF PHOTOSYNTHESIS



Based on the data presented, which of the following statements relating to Figure 3K.30 is correct?

- ☐ A. At low concentrations an increase in the amount of carbon dioxide results in an increase in the rate of photosynthesis.
- ☐ B. An increase in the amount of carbon dioxide in the air beyond 0.2% has an additional effect.
- ☐ C. Carbon dioxide concentrations in excess of 10% are toxic to plants.
- ☐ D. Normal air has a carbon dioxide concentration of approximately 0.3%.
- ☐ E. Light is the limiting factor to the rate of photosynthesis.

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light intensity graphical analysis

Guideline Objective

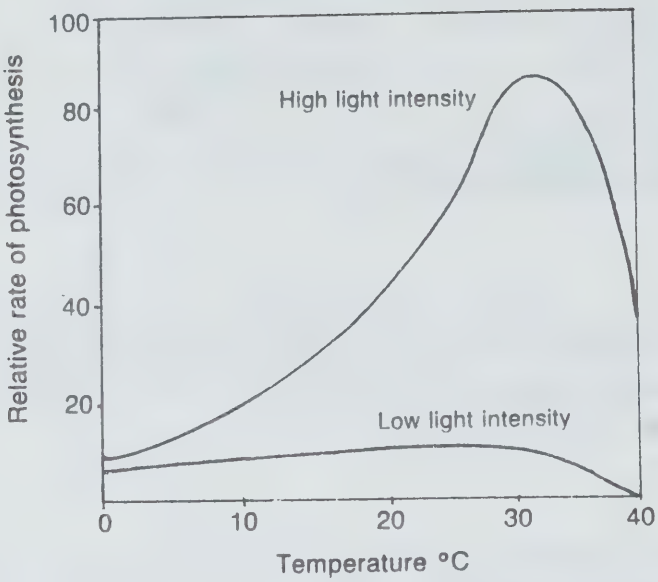
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to describe how the rate of photosynthesis is affected by temperature, based on evidence from experiments.

Item

Refer to Figure 3K.31.



Which of the following statements relating to Figure 3K.31 is correct?

☐ A. At high light intensity, an increase in temperature results in an increase in the rate of photosynthesis to an optimum between 30 - 35°C.

☐ B. At temperatures above 35°C, it is believed that the protein enzymes are denatured.

☐ C. The decline in the rate of photosynthesis above 35°C is attributed to enzyme inactivation.

☐ D. The rate of photosynthesis at high light intensity is governed by enzymatic chemical reactions.

☐ E. At low light intensity, the rate of photosynthesis is not affected by temperature.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Rate of Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KjMC.04
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.5.
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: carbon dioxide concentration

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to identify the effect of a moderate increase in the concentration of carbon dioxide on the rate of photosynthesis.

Item

Assuming that all other factors remained the same, a change to a concentration of 0.1% carbon dioxide in the atmosphere would most likely

☐ A. be toxic to plants.

☐ B. decrease the rate of photosynthesis.

☐ C. increase the rate of photosynthesis.

☐ D. increase water loss through transpiration.

☐ E. have no effect on most plants.

Response/Marking Scheme

Correct response: C

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.05
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11, D.1, D.3
TOPIC: Photosynthesis Rates	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret graphical information based on factors which affect the rate of photosynthesis.

Item

Refer to Figure 3K.29.

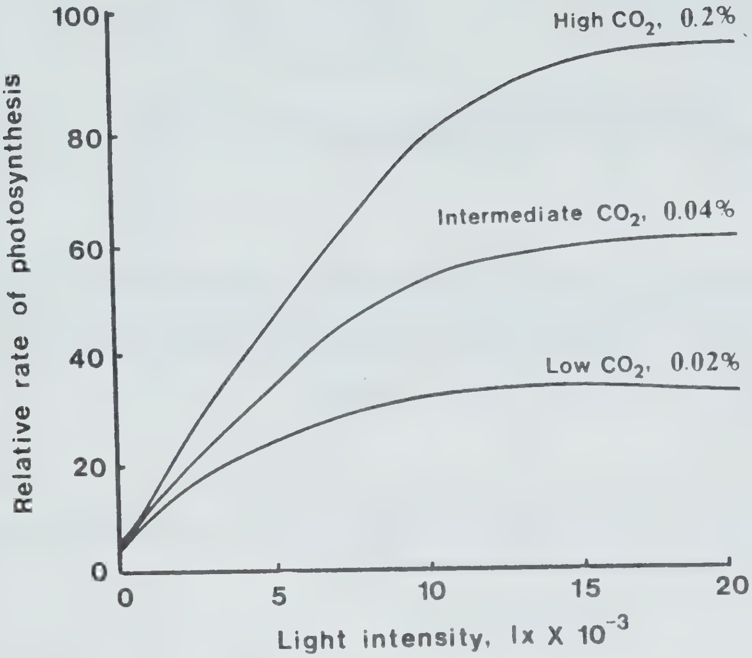


Figure 3K.29 illustrates that

- ☐ A. light is the limiting factor in the rate of photosynthesis.
- ☐ B. an increase in carbon dioxide will decrease the rate of photosynthesis.
- ☐ C. only the light reactions of photosynthesis are taking place
- ☐ D. above a certain light intensity, carbon dioxide limits the rate of photosynthesis.
- ☐ E. the stronger the light intensity, the lower the rate of photosynthesis.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.06
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11, D.1, D.3
TOPIC: Photosynthesis Rates	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret graphical information based on factors which affect the rate of photosynthesis.

Item

Refer to Figure 3K.30.

RATE OF PHOTOSYNTHESIS

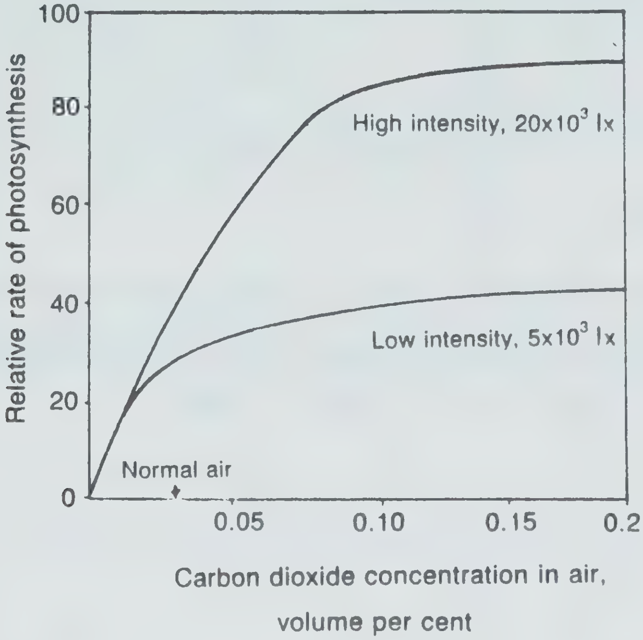


Figure 3K.30 illustrates that

☐ A. light is the limiting factor in the rate of photosynthesis.

☐ B. an increase in carbon dioxide will decrease the rate of photosynthesis.

☐ C. only the light reactions of photosynthesis are taking place.

☐ D. carbon dioxide does not affect the rate of photosynthesis.

☐ E. above a certain light intensity, carbon dioxide limits the rate of photosynthesis.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.07
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11, D.1, D.3
TOPIC: Photosynthesis Rates	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis graphical analysis

Guideline Objective

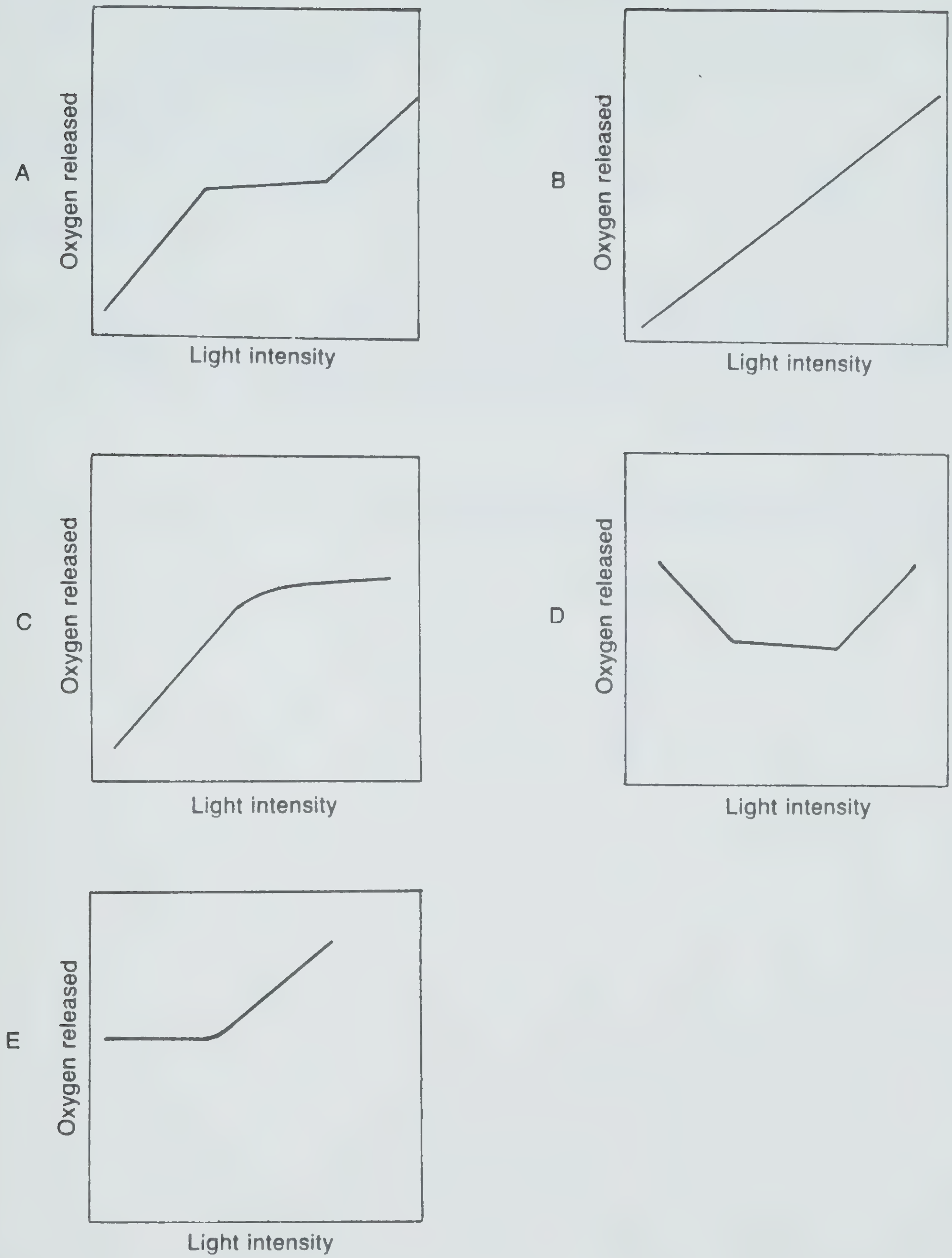
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret graphical information based on factors which affect the rate of photosynthesis.

Item

Refer to Figure 3K.34.



Which of the graphs in Figure 3K.34 best describes the rate of photosynthesis if a variable <u>other than</u> light is the limiting factor?

☐ A.

☐ B.

☐ C.

☐ D.

☐ E.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis Rates
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjMC.08
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.11, D.1, D.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: rate of photosynthesis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret data on factors that affect the rate of photosynthesis.

Item

The following table summarizes the results of an experiment where the volumes of oxygen evolved by two plant species, growing under different light conditions, were compared. Assume that the same biomass of leaves of the two species were used.

Plant	Type of light	Total volume of oxygen evolved (mL)	Temperature (°C)	Time (days)
Coleus	natural	400	20	5
Coleus	artificial	800	22	10
Oats	natural	400	22	5
Oats	artificial	300	22	5

Based on these data, you can compare the volumes of oxygen evolved by

☐ A. *Coleus* and oat leaves under natural light.

☐ B. *Coleus* leaves under natural and artificial light.

☐ C. oat leaves at 20°C and 22°C.

☐ D. oat leaves under natural and artificial light.

☐ E. *Coleus* and oat leaves under artificial light.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.09
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.11, D.1, D.3
TOPIC: Photosynthesis Rates	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: rate of photosynthesis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret data on factors that affect the rate of photosynthesis.

Item

The following table summarizes the results of an experiment where the volumes of oxygen evolved by two plant species, growing under different light conditions, were compared. Assume that the same biomass of leaves of the two species were used.

Plant	Type of light	Total volume of Oxygen evolved (mL)	Temperature (°C)	Time (days)
Coleus	natural	400	20	5
Coleus	artificial	800	22	10
Oats	natural	400	22	5
Oats	artificial	300	22	5

Which of the following statements is a valid interpretation of the data?

☐ A. In natural light, *Coleus* gives off more oxygen per day than does oats.

☐ B. At 22°C, *Coleus* gives off more oxygen than oats.

☐ C. In natural light, both *Coleus* and oats give off the same amount of oxygen.

☐ D. Less oxygen is evolved per day in natural light than in artificial light.

☐ E. Oxygen production is more rapid in oats in natural light than in artificial light.

Response/Marking Scheme

Correct response: E

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Rate of Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjMC.10
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, B.1, D.1
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: photosynthesis respiration

Guideline Objective

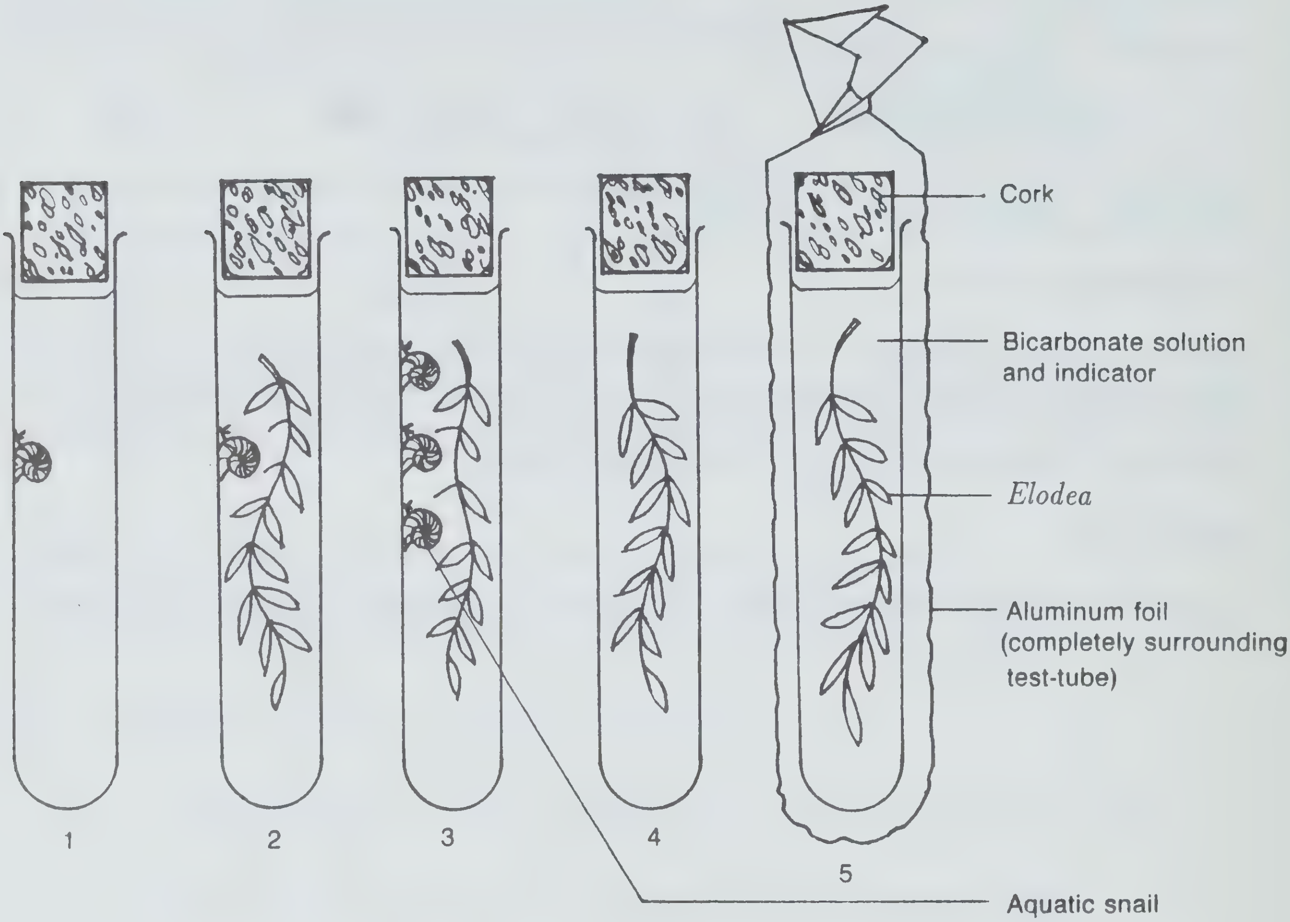
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret the results of experiments involving both photosynthesis and respiration.

Item

Refer to Figure 3K.35 and the two tables which follow.



An indicator was added to each of the five test tubes shown in Figure 3K.35. The table below shows you the colour of the indicator solutions in various concentrations of carbon dioxide:

Table 1

Colour of pH indicator solution	Relative carbon dioxide concentration
yellow	high
red	medium (comparable to the concentration in the atmosphere)
purple	low

Table 2 shows the results of the experiments, after the test tubes have been allowed to stand under natural light for several hours.

Table 2

Observations	1	2	3	4	5
initial colour of indicator	red	red	red	red	red
Final colour of indicator	yellow	red	yellow	purple	red

The following are statements which apply to the results of this experiment:

I Respiration is taking place in all five test tubes.
II Respiration is exceeding photosynthesis in Test Tube #3
III Photosynthesis is occurring in Test Tube #5
IV The lowest concentration of carbon dioxide is found in Test Tube #2

Which of the above statements are correct?

☐ A. II and III

☐ B. I and II

☐ C. I and IV

☐ D. II and IV

☐ E. III and IV

Response/Marking Scheme

Correct response: B

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Rate of Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjMC.11
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, B.1, D.1
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: photosynthesis respiration

Guideline Objective

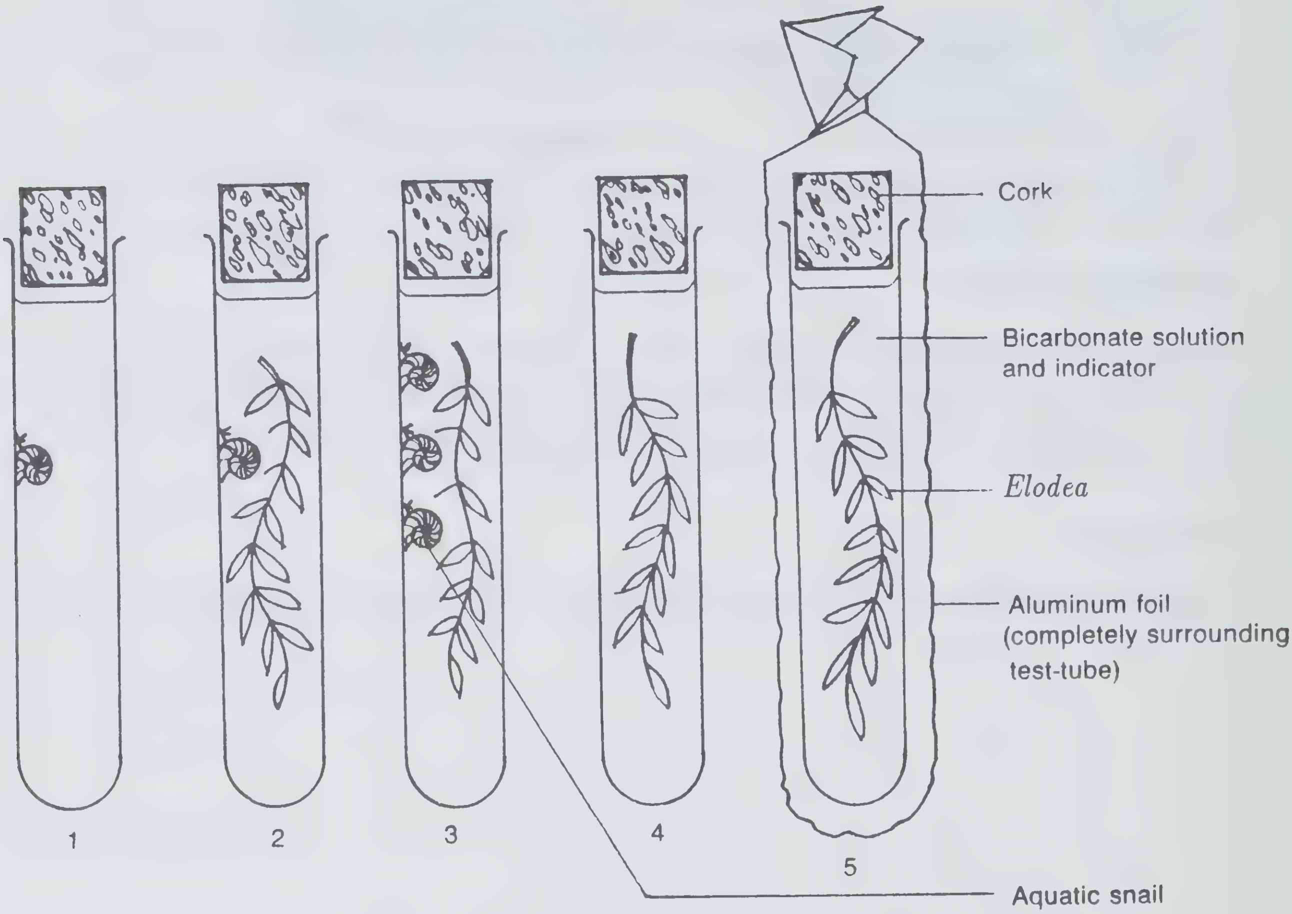
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret the results of experiments involving both photosynthesis and respiration.

Item

Refer to Figure 3K.35 and the two tables which follow.



An indicator was added to each of the five test tubes shown in Figure 3K.35. The table below shows you the colour of the indicator solutions in various concentrations of carbon dioxide:

Table 1

Colour of pH indicator solution	Relative carbon dioxide concentration
yellow	high
red	medium (comparable to the concentration in the atmosphere)
purple	low

Table 2 shows the results of the experiments, after the test tubes have been allowed to stand under natural light for several hours.

Table 2

Observations	1	2	3	4	5
initial colour of indicator	red	red	red	red	red
Final colour of indicator	yellow	red	yellow	purple	red

The colour of the bicarbonate indicator could be changed from red to purple in Test Tube #5 by

☐ A. removing the covering from the test tube.

☐ B. adding more *Elodea*to the test tube.

☐ C. adding snails to the test tube.

☐ D. placing the test tube in a red light.

☐ E. removing some of the *Elodea*.

Response/Marking Scheme

Correct response: A

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.12
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, B.1, D.1
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: photosynthesis respiration

Guideline Objective

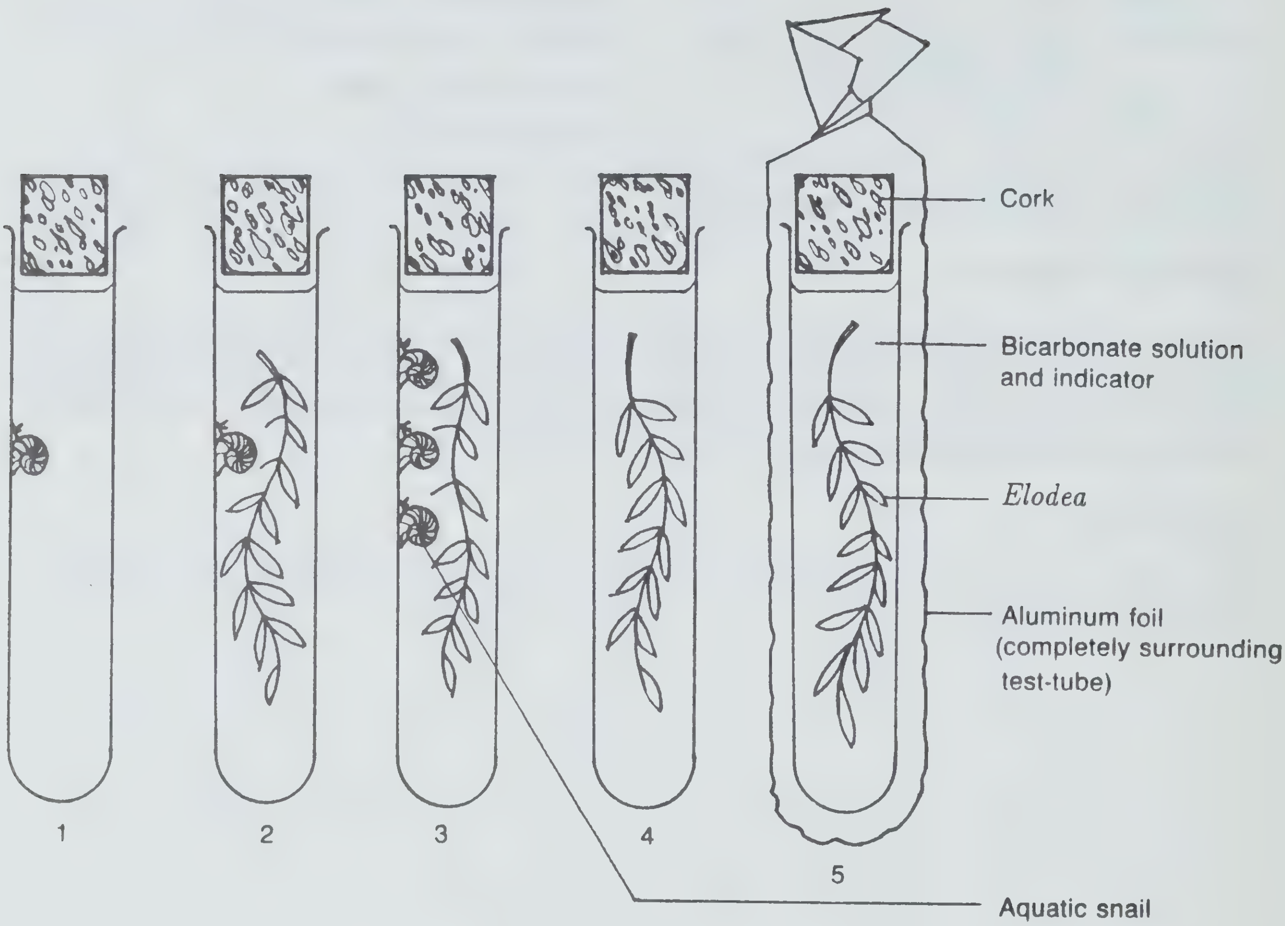
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to interpret the results of experiments involving both photosynthesis and respiration.

Item

Refer to Figure 3K.35 and the two tables which follow.



An indicator was added to each of the five test tubes shown in Figure 3K.35. The table below shows you the colour of the indicator solutions in various concentrations of carbon dioxide:

Table 1

Colour of pH indicator solution	Relative carbon dioxide concentration
yellow	high
red	medium (comparable to the concentration in the atmosphere)
purple	low

Table 2 shows the results of the experiments, after the test tubes have been allowed to stand under natural light for several hours.

Table 2

Observations	1	2	3	4	5
initial colour of indicator	red	red	red	red	red
Final colour of indicator	yellow	red	yellow	purple	red

The colour of the bicarbonate indicator could be changed from yellow to red in Test Tube #3 by

☐ A. covering the test tube with tin foil.

☐ B. adding snails to the test tube.

☐ C. adding more *Elodea*to the test tube.

☐ D. placing the test tube in a red light.

☐ E. removing some of the *Elodea*.

Response/Marking Scheme

Correct response: C

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjMC.13
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj Part 1(3.2-8a)
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.4, C.2, I.1
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: hypothesis photosynthesis carbon dioxide concentration.

Guideline Objective

The students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light- dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature, and the intensity, type, and duration of light.

Item Focus

The student will identify an appropriate prediction resulting from a specific conditional statement, in order to complete an hypothesis.

Item

An hypothesis can be a statement in the form "if something is true, then something else should happen". The part of the statement after the "then" is usually a prediction that can be experimentally tested. Choose the most appropriate ending to complete the following hypothesis.

If increasing the concentration of carbon dioxide increases the rate of photosynthesis, then

☐ A. increasing the temperature should increase the rate of oxygen production.

☐ B. increasing the duration of light should increase the rate of photosynthesis.

☐ C. increasing the concentration of carbon dioxide should increase the rate of glucose production.

☐ D. increasing the concentration of carbon dioxide should decrease the rate of glucose consumption.

☐ E. changing the quality of light should change the rate of glucose production.

Response/Marking Scheme

Correct response: C.

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.8, A.10, C.2, D.2 - 4
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light-dependent reactions light-independent reactions graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

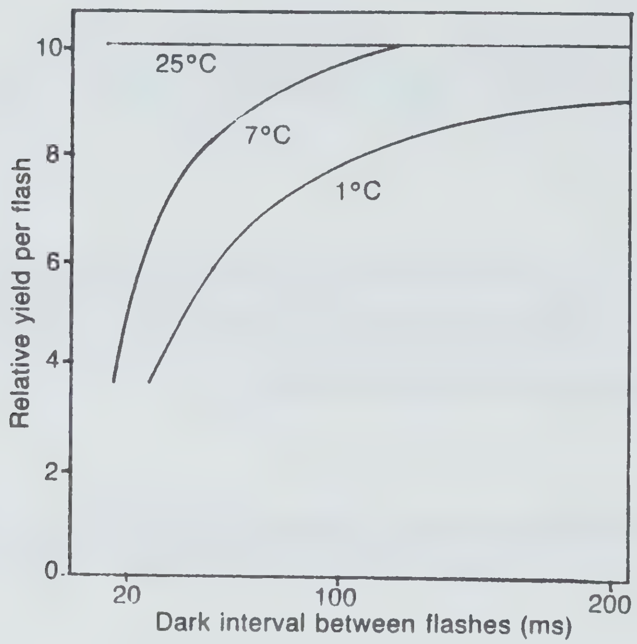
Item Focus

The student should be able to interpret experimental data on the efficiency of photosynthesis in relation to temperature and the duration of the interval between flashes of light.

Item

Refer to Figure 3K.38.

EFFICIENCY OF THE TRANSFER OF ENERGY FROM FLASHES OF LIGHT



The graph in Figure 3K.38 shows the efficiency with which light energy, absorbed by a plant in a flash of uniform duration, is converted into chemical potential energy as a function both of temperature and of the duration of the dark intervals between flashes. Interpret the data in terms of your knowledge of the light-dependent and the light-independent reactions of photosynthesis.

Response/Marking Scheme

The light-dependent reactions occur only during the flash	1
and result in the generation of some standard quantity of ATP and reduced NADP (because the flashes are uniform).	1
These are consumed by the light-independent ("dark") reactions both during the standard flash of light and during the variable dark interval.	1
The maximum efficiency of conversion of energy will occur if all the ATP and reduced NADP are consumed before the next flash appears.	1
This appears to be the case at 25°C since the line can be extrapolated horizontally to meet the abcissa at a dark interval of 0 ms.	1
While both light-dependent and light-independent reactions may be slowed at lower temperatures,	1
it appears that light-independent reactions are slower at lower temperatures than the light-dependent reactions,	1
since it takes about 100 ms for the light-independent reactions to use up all the ATP and reduced NADP generated by a single flash of light at 7°C,	1
and probably a great deal more than 200 ms for them to do this at 1°C.	1
This would be expected because there are many more interactions between enzymes and substrates required during the light-independent reactions than during the light-dependent reactions,	1
and also because the enzymes involved in the light-independent reactions are not as firmly held in position within the chloroplast as those of the light-dependent reactions.	1
Possible:	11
Maximum:	8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, C.1, C.2, F.1
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phosphoglyceraldehyde (PGAL) rate of photosynthesis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to explain the effect of increasing light intensity on the rate of photosynthesis.

Item

How do increases in light intensity affect the production of phosphoglyceraldehyde (PGAL) in a photosynthesizing plant?
Explain your answer.

Response/Marking Scheme

The amount of PGAL produced would increase	1
with increasing light intensities	1
to a maximum.	1
PGAL is produced in the light-independant reaction of	1
photosynthesis, but its production is dependent on	1
the ATP and NADPH + H^+ of the light-dependent reaction.	2
Possible:	7
Maximum:	6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, C.1, C.2, F.1
TOPIC: Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: phosphoglyceraldehyde (PGAL) carbohydrate

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to explain the effect of increasing the concentration of carbon dioxide on the rate of photosynthesis.

Item

Carbohydrate is a product of the light-independent reaction of photosynthesis.How does an increase in the concentration of carbon dioxide affect the production of carbohydrate in a photosynthesizing plant? Explain your answer.

Response/Marking Scheme

Increasing concentrations of carbon dioxide should increase the amount of carbohydrate to a maximum.	1
Ribulose-1, 5-diphosphate (RDP)	1
accepts the carbon dioxide and through a series of reactions produces carbohydrate.	1
Possible:	3
Maximum:	3

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KjLA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kj
UNIT NUMBER: 03	INSTRUMENT TYPE: LA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A1, A.2, A.3, D1, D3
TOPIC: Rate of Photosynthesis	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: light quality von Engelmann

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student will, based on evidence from experiments, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature, light intensity and quality, and light duration (photoperiod).

Item

Refer to Figure 3K.39.

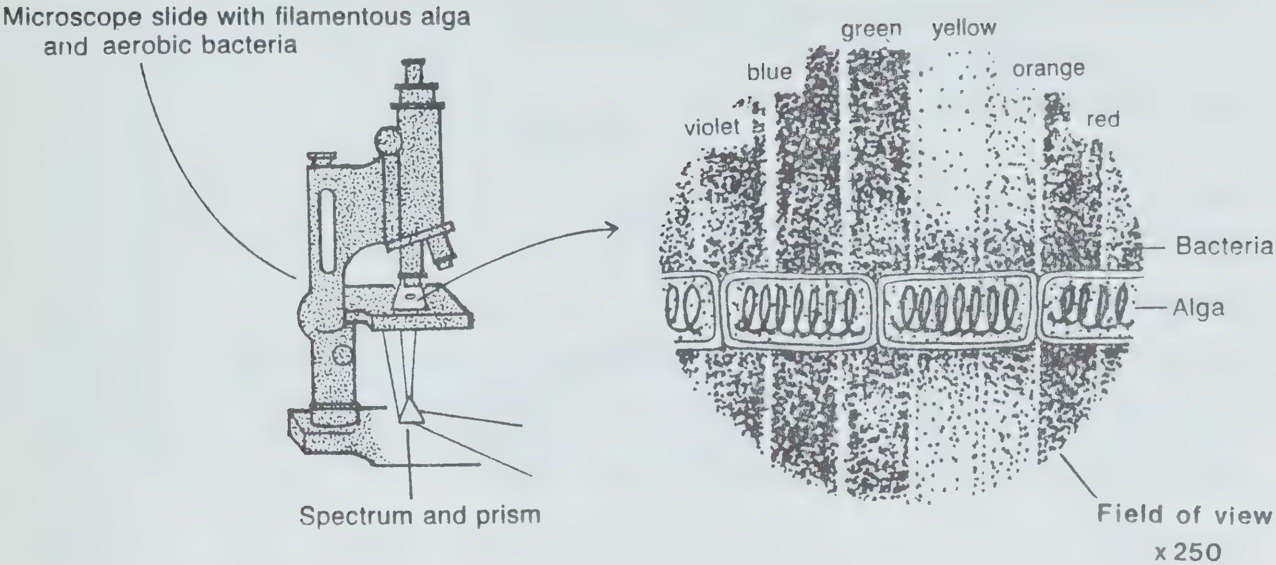


Figure 3K.39 illustrates an experiment first performed by von Engelmann, in which light was allowed to pass through a prism before being used to illuminate a strand of green alga. The prism broke the light into its component colours. Motile aerobic bacteria were allowed to come in contact with the alga and the distribution they achieved is indicated by the small dots drawn around the alga. Explain the observations.
(Assume that the intensity, measured in photons arriving in a unit of area each unit of time, is equal for all colours of the spectrum.)

Response/Marking Scheme

The bacteria are motile and, so, they are able to select optimum growing conditions,	1
which, for them, would be areas where molecular oxygen (O_2) is most plentiful.	1
This apparently is the case in red light	1
and, to a lesser degree, in blue light.	1
Since oxygen is a by-product of photosynthesis,	1
the experiment indicates that this alga uses red wavelengths of light for photosynthesis	1
and is also able to use blue light to some extent.	1
Possible:	7
Maximum:	5

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Conditions Affecting Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjLA.02
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: LA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.3, F.1,I.4
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: light intensity graphical analysis

Guideline Objective

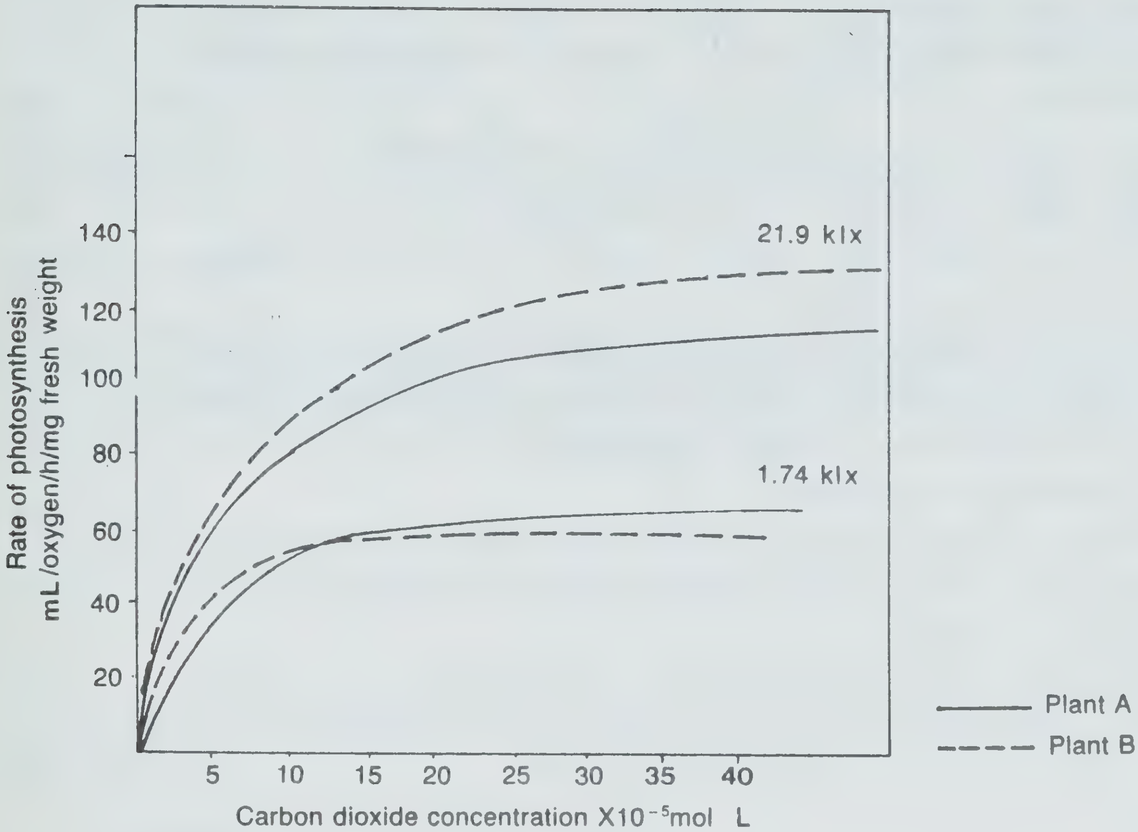
Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student will, based on evidence from experiments, describe how the rate of photosynthesis is affected by light intensity.

Item

Refer to Figure 3K.40.



The results shown in Figure 3K.40 were obtained when two different plants were grown at two different light intensities.

A. Explain the results in terms of your knowledge of photosynthesis.

B. How might the data shown be applied by a grower to plants grown in a greenhouse?

Response/Marking Scheme

A. The shape of all four curves is similar in that they increase at a regular rate to the point where carbon dioxide is no longer limiting, when they level off to a plateau. 2

The effect of higher light intensity is to increase the rate of photosynthesis for both plants, 1

and reaching a plateau for a higher level of carbon dioxide. 1

More light increases the rate of the light reaction 1

making more high-energy molecules available for carbon fixation, utilizing carbon dioxide more efficiently. 1

Plant B, at higher light intensity, outperforms Plant A because some plants have a higher capacity for the different processes of photosynthesis. 1

At lower light intensity, Plant A outperforms B. 1

B. Application to a greenhouse:

Knowing the levels of light and carbon dioxide that promote maximum efficiency of photosynthesis permits the grower to provide optimal conditions to increase 1

productivity and yet minimize cost by not exceeding the maximum levels. 1

Possible: 10

Maximum: 10

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Respiration and Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjLA.03
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: LA
KLOPFER: A.1, A.2, A.3, A.10, A.11, D.1, D.2, D.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: respiration photosynthesis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

Same as above.

Item

A pH indicator solution changes colour depending on the concentration of carbon dioxide present.

Red: less than 0.03%

Orange: is at 0.03%

Yellow: greater than 0.03%

Three flasks are set up containing equal amounts of the bicarbonate indicator solution. All three are exposed to sunlight. The flasks differ in that:

Flask A contains 5 g of *Spirogyra* (a green alga), and the flask is covered with black paper.

Flask B contains 5 g of *Spirogyra.*

Flask C contains only the indicator solution.

At the beginning of the experiment, all the solutions were orange. After 30 min, one of the flasks remained orange while two had changed colour.

A. Indicate the expected colour changes in the three flasks.
B. Explain the final colour of the solution in each flask.
C. This experiment lacks a suitable control. Describe the conditions necessary for a fourth flask to provide an adequate control.

Response/Marking Scheme

A. Expected results.

Flask A - turns yellow 1

Flask B - turns red 1

Flask C - stays orange 1

B. Explanation

Flask A

The black paper prevents photosynthesis. 1

Respiration can occur at its normal rate. 1

Carbon dioxide is released, 1

and dissolves in water. This increases the carbon dioxide concentration in the solution causing the indicator to turn yellow. 1

Flask B

Spirogyra in the light photosynthesizes at a rate 1

exceeding that of its rate of respiration. 1

There is a net intake of carbon dioxide, 1

reducing the concentration of carbon dioxide in the solution, resulting in a change of the indicator 1

to red.

Flask C

This flask was set up as a control, 1

containing no living material. 1

Since there was no colour change, it appears that light alone does not affect the carbon dioxide concentration. 1

Therefore, the changes in the two other flasks were the result of some condition within them. 1

C.

Flask D

This flask contains indicator solution, 1

contains no living material, 1

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis Rate Factors
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjLP.01
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: LP
KLOPFER: A.1, A.3, A.7, B.1, B.2, C.4, D.3, G.1, G.2
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: starch test light quality lab

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able to describe how the rate of photosynthesis is affected by light quality, based on evidence from experiments.

Item

You will be given two leaves from the same kind of plant, marked X and Y. Your task is to determine which of the leaves has been exposed to red light, and which to green light.

A. Write a concise laboratory report listing the major points in your procedure. Give the reasons for each step.
B. Record your observations.
C. Explain your interpretation of the observations.

CAUTION: Ethanol is a volatile liquid which evaporates to form a flammable vapour, consequently it must be kept well away from an open flame.

Materials: 2 leaves
200 mL and 500 mL beakers
hot plate
forceps
white tile
ethanol
iodine solution
water

Response/Marking Scheme

Procedure:

a. Boil leaf in water to remove the cuticle and kill cells, rendering them permeable. 2

b. Then boil leaf in alcohol to extract the chlorophyll, to prevent masking the results of the starch test. 1

c. Then add iodine to the leaf to test for starch. 1

Observations:

Record results of starch test 2

Interpretation:

1. The pigments present in the chloroplasts of leaves, mainly chlorophyll *a* and *b*, are capable of absorbing the red light and converting it to the chemical energy essential for photosynthesis. 1

2. The chloroplasts cannot absorb green light, as evidenced by the transmission or reflection of the green light by the leaf. 1

3. Hence the leaf with the positive starch test, 1
having formed sugar for photosynthesis, must have been the one exposed to the red light. 1
Leaf with negative test result was exposed to green light. 1

Possible: 11

Maximum: 10

Teacher Notes

1. It is assumed that the student knows how to perform a starch test on a leaf efficiently and safely, and is familiar with the water bath method of boiling alcohol, with the burner flame extinguished. If available, use a hot plate to avoid the use of a Bunsen burner completely.

2. If using Bunsen burners, draw the student's attention to the caution note on the instructions.

3. Allow starch present in the experimental plants to be removed from the leaves by keeping the plants in a darkened cupboard for 48 h, or for as long as is necessary. Test to confirm the absence of starch.

4. Expose one plant—geranium, coleus, impatiens—(or more depending on how many leaves are required) to red light for 48 h and another plant to green light for the same period of time.

5. Use a well-ventilated, large cupboard, a darkened room, or, ideally, a blacked-out, temperature-controlled, climatorium, with a coloured bulb.

6. Red and green Christmas light bulbs are usually obtainable or use light source boxes and filters from the school's physics department.

7. Standardize all of the factors affecting the plants, except the colour of the light.

8. Test a leaf from each plant before giving the leaves to the students to confirm:

   red, positive starch test; green, negative starch test.

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Rate of Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjSA.01
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, D.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: carbon dioxide fixation aerobic respiration graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

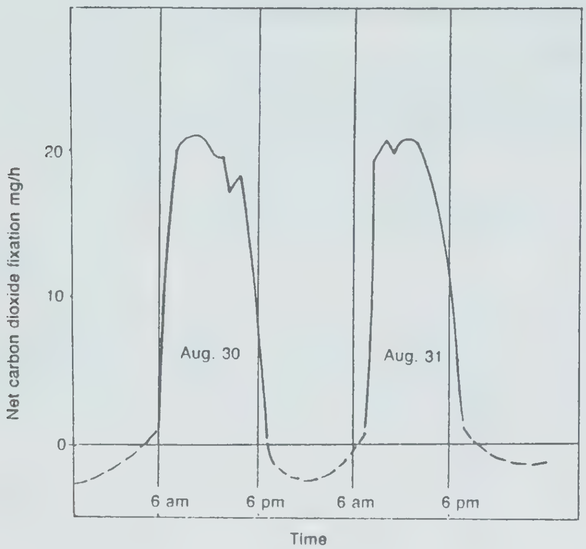
Item Focus

The student should be able to interpret graphical data as it relates to the fixation of carbon dioxide during photosynthesis.

Item

Refer to Figure 3K.41.

NET CARBON DIOXIDE FIXATION AGAINST TIME:
A PLOT OF ALFALFA OVER A TWO DAY PERIOD



Source: Salisbury and Ross
Plant Physiology
pp. 161.,Fig. 11-2

from data of Thomas and Hill, 1949
Photosynthesis in Plants
Iowa State University Press.

A. At what time of day is the rate of carbon dioxide fixation at a maximum?

B. Why might this be?

C. Give a possible explanation for the drop in the rate of carbon dioxide fixation in the early afternoon of the 30th and just before noon on the 31st.

D. Explain the negative carbon dioxide fixation values.

E. Name the processes involved and compare their rates.

Response/Marking Scheme

A.	About noon.	1
B.	Light intensity is at its highest at this time.	1
C.	Light is the limiting factor; intensity drop possibly due to cloud cover.	2
D.	This is due to the release of carbon dioxide during respiration.	1
E.	Photosynthesis and aerobic respiration	2
	Relative rate of photosynthesis (maximum rate 21) and respiration (max. rate 2.5)	1
	Photosynthetic rate approximately 8 times that of respiration.	1
	Possible:	9
	Maximum:	7

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology

LEVEL: OAC

UNIT NUMBER: 03

UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

TOPIC: Rate of Photosynthesis

CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjSA.02

GUIDELINE OBJECTIVE CODE: 31Kj

INSTRUMENT TYPE: SA

KLOPFER: A.1, A.2, D.1, D.3, D.6

DIFFICULTY LEVEL:

TIME ALLOCATION:

KEYWORDS: ribulose diphosphate light-dependent reaction light-independent reaction graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

Same as above.

Item

Refer to Figure 3K.42.

EFFECT OF THE PRESENCE AND ABSENCE OF LIGHT ON RDP IN PHOTOSYNTHESIZING TISSUE (*Chlorella*)

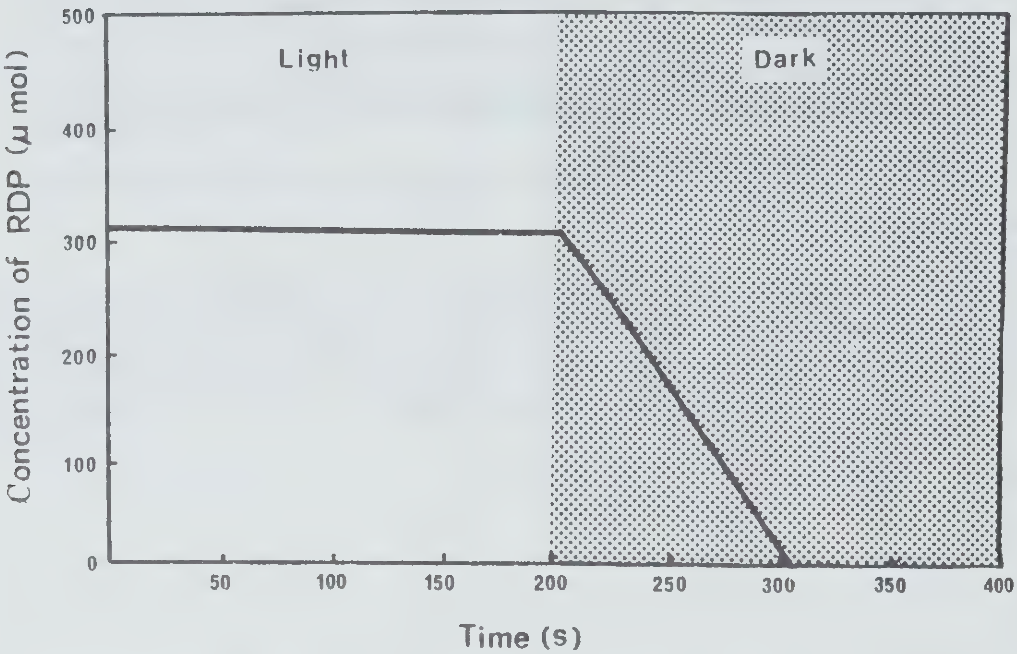


Figure 3K.42 shows the effect of the presence of light on RDP in photosynthesizing tissue (*Chlorella*) explain the observed results.

Response/Marking Scheme

The RDP in the light is being utilized at the same rate as it is being produced,	2
In the dark, it is still being used as the initial receptor of the CO_2 molecule,	1
but it is not being replenished because	1
the light-independent reactions have stopped	1
due to a lack of reactants (ATP, NADPH + H^+).	2
Possible:	7
Maximum:	5

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Rate of Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KjSA.03
GUIDELINE OBJECTIVE CODE: 31Kj
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, D.1, D.3, D.6
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: phosphoglyceric acid (PGA) light-dependent reaction graphical analysis light-independent reaction. graphical analysis

Guideline Objective

Students will be expected to, on the basis of evidence from experiments and in terms of the relationship between the light-dependent and light-independent reactions of photosynthesis, describe how the rate of photosynthesis is affected by carbon dioxide concentration, temperature and the intensity, type and duration of light.

Item Focus

The student should be able interpret the results of experiments showing light-dependent and light-independent reactions.

Item

Refer to Figure 3K.42.

EFFECT OF THE PRESENCE AND ABSENCE OF LIGHT ON PGA IN PHOTOSYNTHESIZING TISSUE (*Chlorella*)

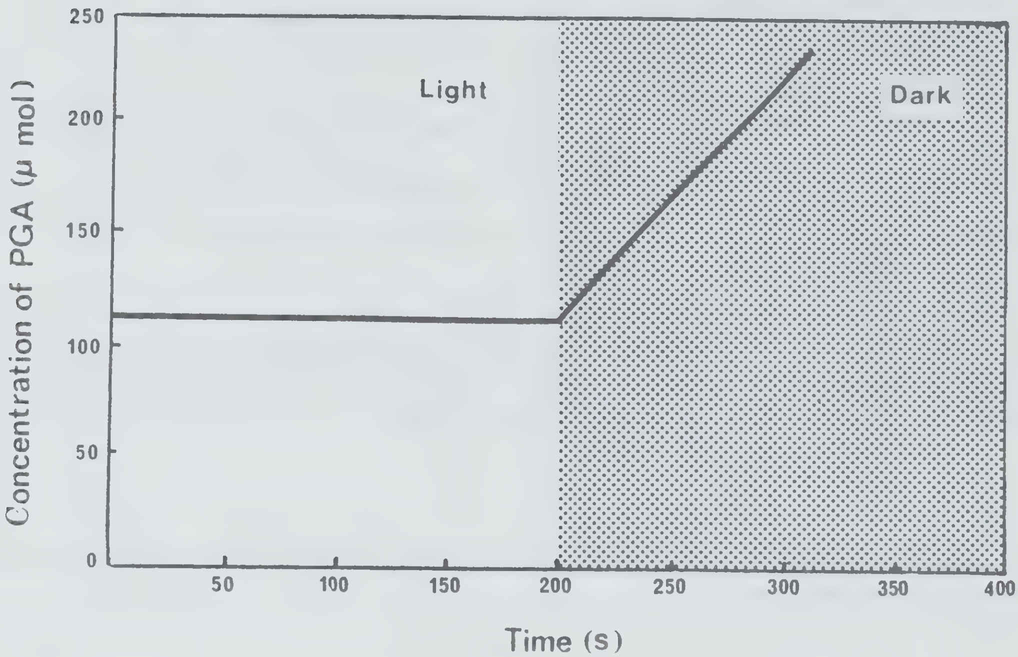


Figure 3K.42 shows the effect of the presence and absence of light on PGA in photosynthesizing tissue. (*Chlorella*). Explain the observed results.

Response/Marking Scheme

In the dark, the PGA accumulates in the plant tissue because ATP and NADPH + H^+ are no longer supplied. 1

In the light, there is an equilibrium, since the products of the light-dependent reaction (ATP, NADPH + H^+) are 2

reduced to PGAL. 1

Possible: 5

Maximum: 5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KkMC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kk
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, I.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Solid Foundations	TIME ALLOCATION:

KEYWORDS: Calvin *Chlorella* carbon fixation.

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

The student should be able to recognize the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item

Which of the following statements about Calvin's work with *Chlorella* in determining the carbon fixation cycle are correct?

I *Chlorella* shows individual variation
II *Chlorella* is unicellular
III *Chlorella* is easily grown
IV There is much background information available
V *Chlorella* photosynthesizes

Select your response from

☐ A. I, III only.

☐ B. II, V only.

☐ C. II, III, V only.

☐ D. II, III, IV, V only.

☐ E. III, IV, V only.

Response/Marking Scheme

Correct response: D

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B031KkMC.02
GUIDELINE OBJECTIVE CODE: 31Kk
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.5, I.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: Calvin chromatography radioactive isotope

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

The student should be able to recognize the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item

Which of the following were involved in Calvin's work in photosynthesis?

I radioactive carbon (^{14}C)
II *Coleus*
III chromatography
IV electrophoresis
V radioautography
VI *Chlorella*

Select your answer from

☐ A. I, II only

☐ B. I, VI only

☐ C. II, III, V only

☐ D. IV, VI only

☐ E. I, III, V, VI only

Response/Marking Scheme

Correct response: E

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KkER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kk
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A., A.2, A.3
TOPIC: Calvin Cycle	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: radioactive isotope *Chlorella*

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

As above

Item

The problem of how carbon dioxide is converted to carbohydrates was solved by Melvin Calvin and associates at the University of Berkeley in California in the 1950's. The importance of the work was acknowledged by the award of a Nobel Prize in 1961.
Describe the techniques used by Melvin Calvin to determine the carbon fixation (C_3) cycle.

Response/Marking Scheme

They used the radioactive isotope of carbon, ^{14}C. 1

to detect and identify the compounds in which carbon 1

from carbon dioxide first appeared during photosynthesis. 1

These compounds rapidly became radioactive when *Chlorella*, a green alga, was given $^{14}CO_2$ in the light. 1

In the actual experiments, radioactive carbon dioxide was injected into a chamber containing *Chlorella*. After only 1

5 s, the cells were immediately killed in boiling 1

alcohol. Even after this short interval of time 1

the scientists identified five different compounds, alanine, malic acid, sucrose, phosphorylated sugars, and 1

phosphoglyceric acid.

An attempt was made to shorten the time of exposure to the radioactive carbon dioxide to establish the first chemical 1

to become radioactive. In practice, this proved impossible to do. 1

Possible: 10

Maximum: 8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KkER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kk
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, D.1, D.2, D.3, D.6
TOPIC: Calvin Cycle	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: radioactive isotope carbon fixation

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

Same as above

Item

During the 1950's, Melvin Calvin and his associates at the University of Berkeley, in California, carried out a number of ingenious experiments. They were trying to find out how carbon dioxide is converted into carbohydrates during the light independent part of photosynthesis.

To do this they injected radioactive carbon dioxide into a culture of *Chlorella*, a green alga, under bright light. After a very short period of time, they killed the alga in boiling alcohol and analyzed the cells to find out which chemicals present had become radioactive.

There was a problem, however. Even at very short time intervals, even a few seconds, there were four or five radioactive chemicals present. The question was this. Which chemical first became radioactive? Which chemical was second? In short, what was the sequence in which the chemicals were produced in the living algal cells during photosynthesis?

Assume for the moment that the radioactive carbon dioxide is passed on <u>completely</u> from one compound to the next in a chain of chemical reactions.

You are given the following data:

i) At 2 s, compound A contains 100% of the radioactive carbon dioxide.

ii) At 4 s, there is only radioactive carbon dioxide in compound B.

iii) At 3 s, 45% of the radioactive carbon dioxide is in compound A and 55% is in compound C.

iv) At 3.5 s, 25% of the radioactive carbon dioxide is in compound A and 75% is in compound C.

iv) At no time during the first 5 s is there any radioactive carbon dioxide in compound D.

A. Using the above data, arrange the compounds in a possible sequence, from the first compound formed to the last.

B. Based on the data, what conclusions, if any can you draw about compound D?

C. If you were told that compound D was phosphoglyceric acid (PGA), what data above, if any, supports the idea that it is the first product in the light independent reactions of photosynthesis?

D. With '% compound present' as the y-axis and 'time' as the x-axis, sketch a simple graph indicating what would happen to the amounts of compounds A and C during the first 5 s.

Response/Marking Scheme

A. Based on the above information, the order in which the compounds are formed could be one of the following:

$CO_2 \longrightarrow A \longrightarrow C \longrightarrow B$

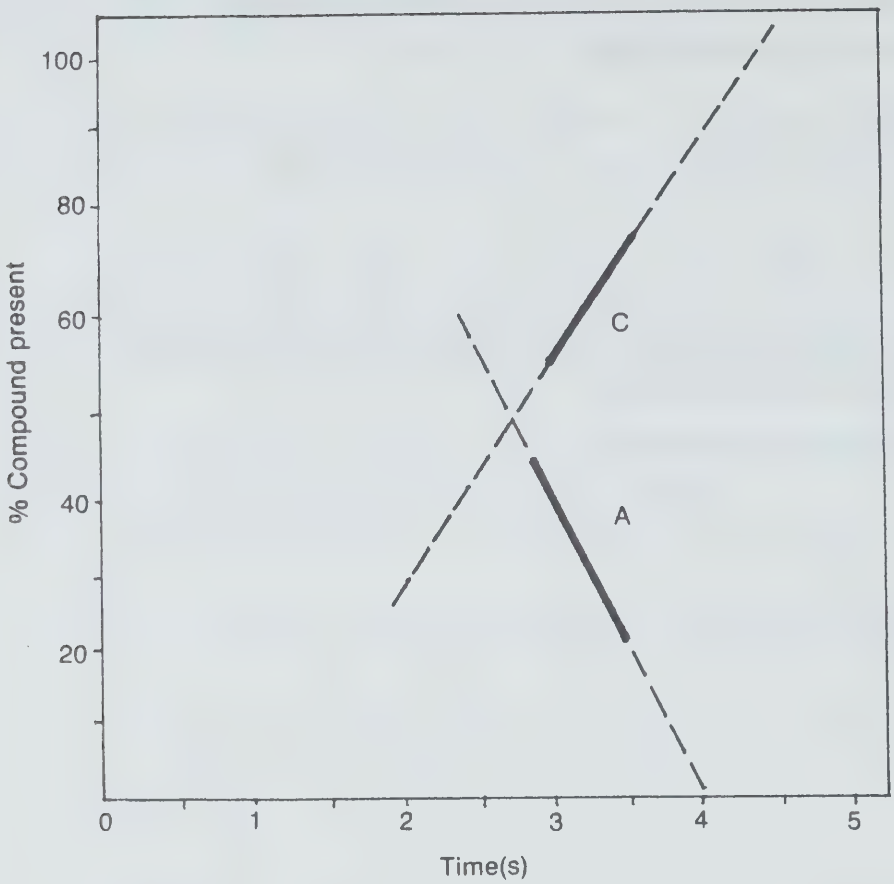
OR 3

$A + CO_2 \longrightarrow C \longrightarrow B$

B. Since compound D does not show up on any of the radioactive analyses, it is imposssible to determine where it 2
might fit into the reaction sequence.

C. There is no data given which supports the view that phosphoglyceric acid is the first product of the light 1
independent reactions of photosynthesis.

D.



4

Possible: 10

Maximum: 10

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KkER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kk
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3, A.5
TOPIC: Light-Independent Reaction	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: radioactive isotope light-dependent reaction

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

The student should be able to explain the relationship of Calvin's experiment to the details of the light-independent reaction of photosynthesis.

Item

Melvin Calvin and his associates won a Nobel prize in 1961 for discoveries made using the radioautography technique to trace the path of carbon in photosynthesis. He used carbon dioxide that contained radioactive carbon ($^{14}CO_2$) to study the process.

A. Was he studying the light-dependent or the light-independent ("dark") phase of photosynthesis? Explain your answer.

B. Describe the events in the carbon pathway according to Calvin's model.

C. Why are ATP and NADPH + H^+ important to the process?

Response/Marking Scheme

A. Calvin was studying the light-independent ("dark") reactions, because this is the phase of photosynthesis in which carbon is fixed. 2

B. In the Calvin Cycle, a five-carbon compound reacts with carbon dioxide to produce a six-carbon compound that immediately splits into two 3-carbon compounds. 4

OR

ribulose diphosphate reacts with carbon dioxide to produce 2 molecules of phosphoglyceric acid.

The cycle continues with the 3-carbon (PGA) molecules going through a series of stages to regenerate the original 5-carbon (ribulose diphosphate), and a sugar, the product of photosynthesis. 3

C. ATP and NADPH + H^+ are needed as the energy to power the Calvin cycle. ATP is used to phosphorylate molecules so that they can react with other molecules; and NADPH + H^+ provides hydrogen ions to reduce an acid to an aldehyde. They are produced in the light-dependent reaction, and as long as they are available, the Calvin cycle continues to fix carbon and to produce sugar molecules. 6

Possible: 15

Maximum: 12

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B031KkSA.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 31Kk
UNIT NUMBER: 03	INSTRUMENT TYPE: SA
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, I.3
TOPIC: Photosynthesis	DIFFICULTY LEVEL:
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: Calvin

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

The student should be able to give 4 reasons why Calvin chose the protist, *Chlorella*, for his work on photosynthesis.

Item

Give 4 reasons why Calvin chose the protist, *Chlorella*, for his work on photosynthesis.

Response/Marking Scheme

Any 4 at one mark each.

1. It photosynthesizes.
2. It is easily contained in laboratory conditions.
3. It is unicellular (small).
4. Large populations were used, therefore minimizing individual variation.
5. Much information was available of the organism's physiology.

Maximum: 4

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Photosynthesis
CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B031KkSA.02
GUIDELINE OBJECTIVE CODE: 31Kk
INSTRUMENT TYPE: SA
KLOPFER: A.1, A.2, A.7, I.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: Calvin

Guideline Objective

Students will be expected to describe the techniques used by Calvin to determine the carbon fixation (C_3) cycle.

Item Focus

The student should be able to describe how Calvin was able to stop photosynthesis in *Chlorella* after very short time periods.

Item

Describe briefly how the plant physiologist, Calvin, used radioactive carbon to determine experimentally the intermediate products of the light-independent "dark" reaction of photosynthesis.

Response/Marking Scheme

Calvin set up a system in which a suspension of *Chlorella*	1
travelled through tubing at a known rate,	1
and was killed in boiling methanol (alcohol).	1
He injected $^{14}CO_2$ at varying distances from the killing point.	2
He tested materials at very short time intervals.	1
He used chromatography to separate the different compounds present,	2
and autoradiography to identify which compounds contained ^{14}C.	2
Possible:	10
Maximum:	10

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Chromatography
CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B032d-MC.01
GUIDELINE OBJECTIVE CODE: 32d
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3, A.7, B.2, B.3
DIFFICULTY LEVEL:
TIME ALLOCATION:

KEYWORDS: chromatography R_f value

Guideline Objective

Students are to use paper chromatographyto separate pigments.

Item Focus

The student should be able to quantify rates of migration of compounds in paper chromatography.

Item

During an experiment using paper chromatography, an unknown amino acid moved 2.0 cm from the origin during the time that the solvent front moved 10.0 cm. What would the R_f value of the amino acid be?

- ☐ A. 0.2
- ☐ B. 2.0
- ☐ C. 5.0
- ☐ D. 8.0
- ☐ E. 20.0

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Paper Chromatography
CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B032d-MC.02
GUIDELINE OBJECTIVE CODE: 32d
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: chromatography R_f value

Guideline Objective

Students are to use paper chromatographyto separate pigments.

Item Focus

The student should be able to identify the characteristics of R_f value.

Item

In paper chromatography, the larger the R_f value of the solute, the

- [ ] A. greater its attraction to the solvent relative to its attraction to the paper.
- [ ] B. greater its attraction to the paper, relative to its attraction to the solvent.
- [ ] C. less dense is the substance.
- [ ] D. more substance is dissolved in the solvent.
- [ ] E. more saturated the atmosphere is with solvent.

Response/Marking Scheme

Correct response: A

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B032d-ER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 32d
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.3, A.7, A.10, B.1, B.2, B.3, B.4, C.2, D.3, D.6, F.1, F.2
TOPIC: Chromatography	
CURRICULAR EMPHASIS: Practical Application	DIFFICULTY LEVEL: M
	TIME ALLOCATION:

KEYWORDS:

Guideline Objective

The student will explain the basis for identifying amino acids by paper chromatography.

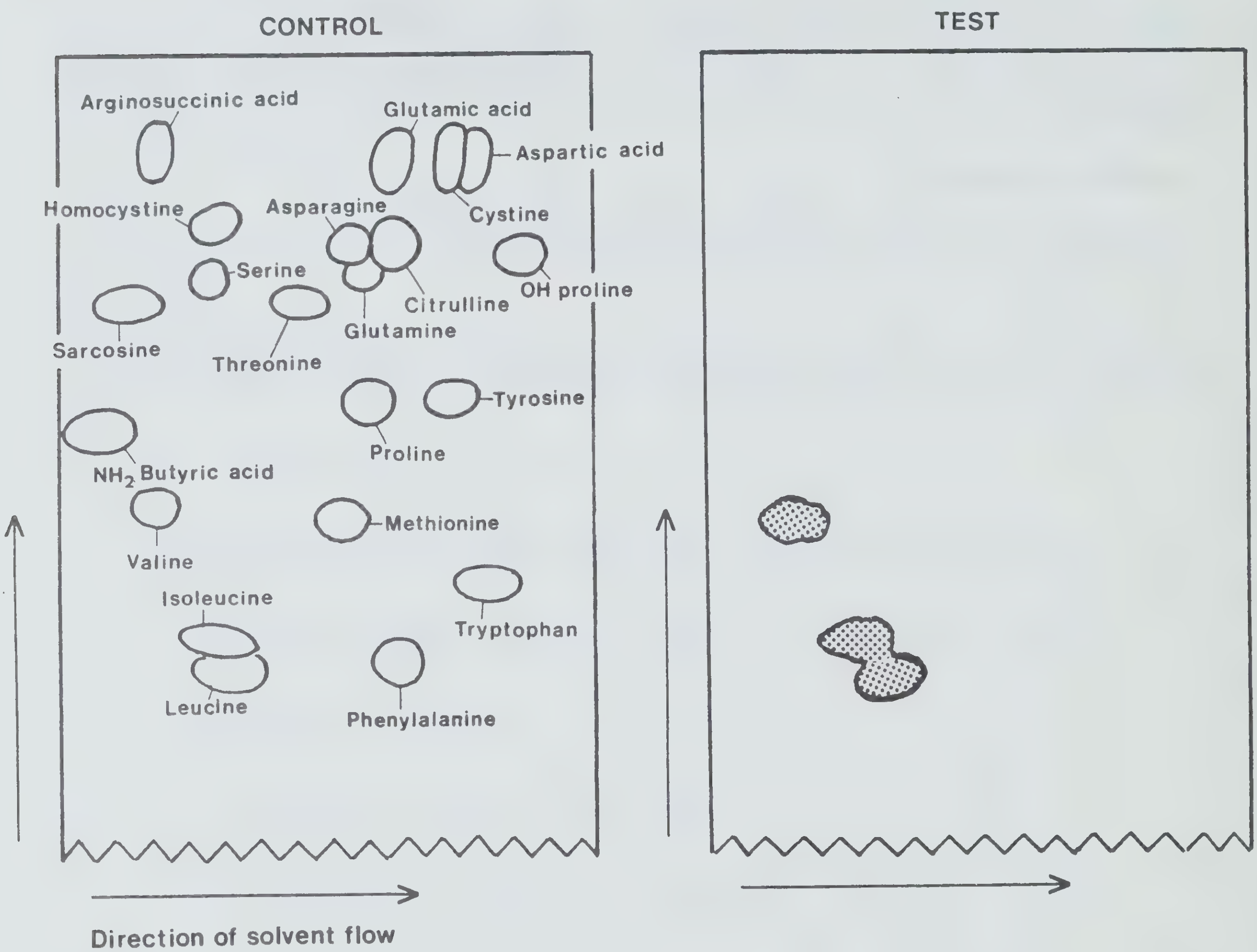
Item Focus

The student should be able to use paper chromatography to analyze a medical problem.

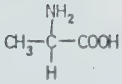
Item

Refer to Figure 3(2).1a and Figure 3(2).1b to answer this question.

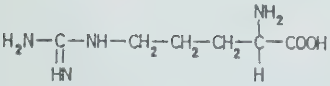
CHROMATOGRAMS FOR THE DETECTION OF SUBSTANCES IN URINE



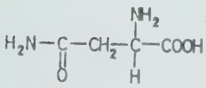
SOME SUBSTANCES THAT COULD BE IN URINE



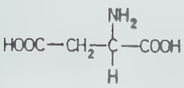
Alanine



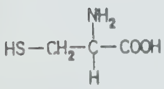
Arginine



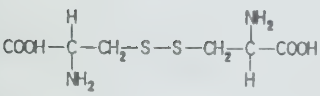
Asparagine



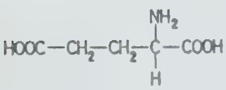
Aspartic acid



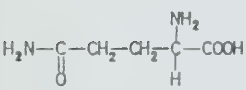
Cysteine



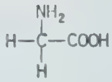
Cystine



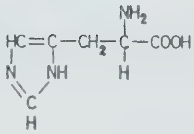
Glutamic acid



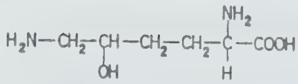
Glutamine



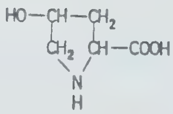
Glycine



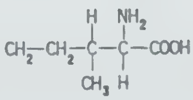
Histidine



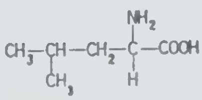
Hydroxylysine



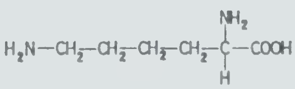
4 - Hydroxyproline



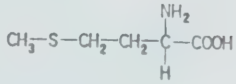
Isoleucine



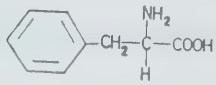
Leucine



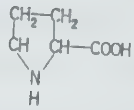
Lysine



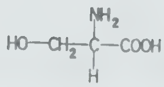
Methionine



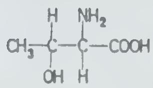
Phenylalanine



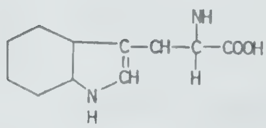
Proline



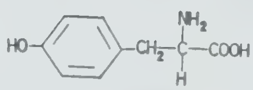
Serine



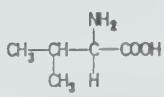
Threonine



Tryptophan



Tyrosine



Valine

Figure 3(2).1a shows that chromatography can be used to detect the presence, in urine, of many substances not normally found in human urine. The chromatogram labelled 'control' shows the locations of known amino acids when pure substances are separated by solvents run in two dimensions. A disease with a Canadian "flavour" (maple syrup urine disease) causes the chromatogram labelled 'test' to develop. This disease is hereditary, being inherited as an autosomal recessive trait.

A. Name the substance(s) that accumulate(s) in the urine during maple syrup disease and explain how you were able to decide.

B. Examine the structural formulae of the substances in the table entitled "Some Substances That Could Be in Urine" (Figure 3(2).1b) and suggest what structural feature was likely responsible for the accumulation of one or more of these substances in urine. Explain your reasoning.

Response/Marking Scheme

A. Valine, leucine, and isoleucine	3
are at elevated levels in the urine. This can be seen because the spots on the test chromatogram occupy positions that correspond to these three substances on the standard (control) chromatogram.	1
B. A branched hydrocarbon chain was responsible since	1
all three accumulated substances have it, and as	1
far as can be checked, no non-accumulated substance that can be detected by the chromatographic technique has it.	1
Other features shared by the three (alpha-carboxyl alpha-amino) are also possessed by other chemicals that would have been detectable, had they been present in the urine, by the chromatographic technique.	1
Possible:	8
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOOGY AND PHOTOSYNTHESIS
TOPIC: Chromatography
CURRICULAR EMPHASIS: Solid Foundation

INSTRUMENT CODE: B032d-ER.02
GUIDELINE OBJECTIVE CODE: 32d
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.3, A.7, F.1
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: chromatogram amino acids.

Guideline Objective

The student will explain the basis for identifying amino acids by paper chromatography.

Item Focus

The student should be able to explain the difference between different methods of chromatography in terms of measurements of R_f values.

Item

There are three ways to locate visually the positions of amino acids on paper chromatograms:

1. view the chromatogram under ultraviolet light, and the amino acids will appear as dark spots,
2. spray the finished chromatogram with ninhydrin, and bake it: the amino acids will appear as blue spots, and
3. treat the amino acid mixture with 1-fluoro-2,4-dinitrobenzene, turning the amino acids into yellow compounds; then chromatograph the mixture and the amino acids appear as yellow spots.

If you were to prepare a standard chromatogram by one of these methods, could you use the R_f values calculated from it to identify amino acids visualized in the other two ways? Explain your reasoning.

Response/Marking Scheme

No!	1
In methods 1 and 2, the spots would occupy the same positions, because the chromatographic process is complete before the amino acids are revealed.	2
Method 3 chemically alters each amino acid	1
before chromatography, and would likely differ in its	1
effects from one amino acid to another in their partition coefficients	1
so it would give different R_f values than the other two.	1
Possible:	7
Maximum:	5

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B032d-LE.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 32d
UNIT NUMBER: 03	INSTRUMENT TYPE: LE
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER:
	DIFFICULTY LEVEL: M
TOPIC: Paper Chromatography	TIME ALLOCATION:
CURRICULAR EMPHASIS: Nature of Science	

KEYWORDS: pigments lab

Guideline Objective

The student will use paper chromatography to separate the pigments in a leaf extract.

Item Focus

The student should be able to separate the pigments in an extract from leaves by means of paper chromatography, and identify the separated pigments.

Item

A. Using the method described below, carry out a separation of the pigments present in the extract of spinach leaves in acetone by paper chromatography.
B. Draw a labelled diagram of your completed apparatus.
C. Attach your chromatograph to a page and
   - label the colour bands
   - identify the pigments
   - calculate the Rf values for the pigments
D. Explain why the pigments separated.
E. Were all the pigments present in the extract separated? If not, why not?

Materials available:

- extract of spinach leaves
- large lest tube with cork
- fine tipped pipette
- Whatman #3 filter paper
- paper clip
- scissors
- test tube rack
- solvent

Safety Precautions:

- This exercise should only be carried out where fume hoods are available.
- The organic solvents used are toxic, volatile, and extremely flammable.
- No open flames should be allowed in the laboratory any time during this exercise.
- The extract and solvents should be poured under a fume hood.
- The filter paper must be dried under a fume hood.

Method:

1. - Cut a strip of filter paper so that it will hang from the cork to the bottom of the test tube, without touching the sides.
2. - Taper one end of the strip of filter paper.
3. - Straighten the paper clip and push into cork in form of hook.
4. - Place solvent in test tube to depth of 2 cm. Re-cork tube.
5. - Place the filter paper strip flat across two supports (pencils) so that it is clear of the bench.
6. - Using the fine-pointed pipette, place a small drop of the extract in the centre of the line drawn at the tapered end of the filter paper.
7. - Allow to dry under the fume hood.
8. - Repeat several times until the spot is dark green. Dry after each addition.
   (Your aim is to build up a high concentration of pigments in the smallest possible area)
9. - Hang the filter paper strip in the test tube so that the tapered 1cm is in the solvent and the extract spot is 1cm above the surface of the solvent. Stand the test tube vertically in a rack.

10. - Observe the rise of the solvent. When it is 2 cm from the top remove the filter paper strip from the test tube.
11. - Quickly mark the position of the solvent front and each of the bands of pigment with a pencil.
12. - Dry under a fume hood.
13. - Complete parts B, C, D, and E of the instrument.

Response/Marking Scheme

B.

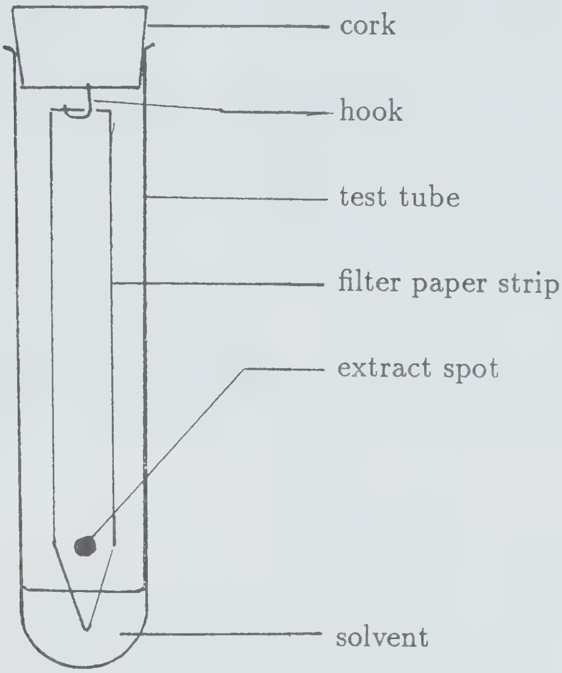
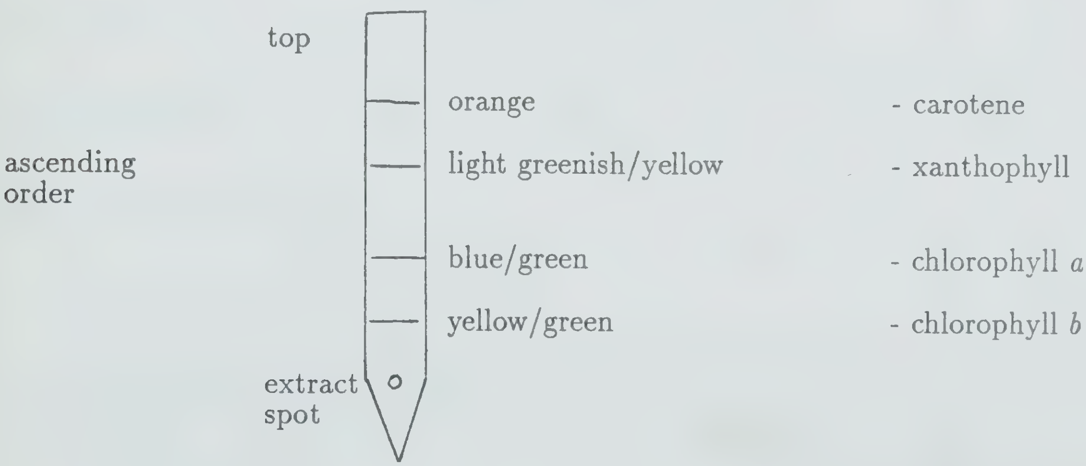


Diagram: 1

Labels: 3

C. Order of colour bands and names of pigments



8

substance	distance travelled from extract spot	Rf value (ratio of fronts)
edge of advancing front of solvent		
carotene		
xanthophyll		
chlorophyll *a*		
chlorophyll *b*		

4

D.

- Solvent moves up filter paper by capillarity. 1
- It dissolves the pigments and takes them with it. 1
- Individual pigments travel at different rates. 1
- The more soluble a pigment is in water, as opposed to the organic solvent, the slower it travels. 1

E.

- No.
- The water soluble pigments (eg. anthocyanins) are not separated by this method. 1

Possible: 22

Maximum: 20

Teacher Notes

- Prepare an extract of the pigments present in spinach leaves (fresh or frozen).

  Caution: This entire operation must be carried out under a fume hood. Acetone is a toxic, volatile, flammable liquid. Students should avoid inhaling the vapour. No open flames are allowed.

- Commercially prepared chlorophyll extract may be purchased from scientific supply companies.
- Chop 15g of fresh or frozen spinach leaves and grind in a mortar with 50ml of 80% acetone and fine sand.
- Allow to stand for 10 min. and grind again.
- Add more acetone and filter through several filter papers in a Buchner funnel. (A blender can be used instead of a pestle and mortar. If you use a blender, make sure that its container is of glass, since acetone will dissolve plastic.)
- Place extract in small stoppered boiling tubes for use by students.
  Pigments present in leaves:
  - chlorophyll *a* - blue/green
  - chlorophyll *b* - yellow/green
  - carotenoids - yellow/orange
    - B-carotene - orange
    - lutein
    - violaxanthrin
    - neoxanthrin
    - xanthophylls - light greenish yellow
  - anthocyanins - blue/red (water soluble)
- Separation of pigments brought about by their relative solublility in the organic solvents.
- Rate of flow calculated by:

$$R_f = \frac{\text{distance pigment travelled}}{\text{distance solvent travelled}}$$

Use your discretion in allowing the marks for the separation if the colour bands do not separate well.

<u>Materials for the Laboratory:</u>

- Extract of spinach leaves
- large test tubes with corks
- fine tipped pipette or capillary tubing, or melting point tube
- large Whatman #3 filter papers
- paper clips or small screw in hooks
- scissors
- test tube racks
- solvent (mixture of 9 petroleum ether : 1 acetone)

DRAFT

DISCIPLINE/SUBJECT: Science/Biology

LEVEL: OAC

UNIT NUMBER: 03

UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS

TOPIC: Chromatography

CURRICULAR EMPHASIS: Nature of Science

INSTRUMENT CODE: B032d-LP.01

GUIDELINE OBJECTIVE CODE: 32d

INSTRUMENT TYPE: LP

KLOPFER: A.1, A.2, A.3, A.7, A.8, A.9, A.10, B.1, B.3, B.5, C.2, D.3, D.5, D.6, F.1

DIFFICULTY LEVEL: H

TIME ALLOCATION:

KEYWORDS: chromatogram comparative biochemistry.

Guideline Objective

The student will explain the basis for identifying amino acids by paper chromatography.

Item Focus

The student should be able to apply knowledge of chromatography to problems other than the identification of amino acids.

Item

Refer to Figure 3(2).2 to answer this question.

TWO DIMENSIONAL CHROMATOGRAMS

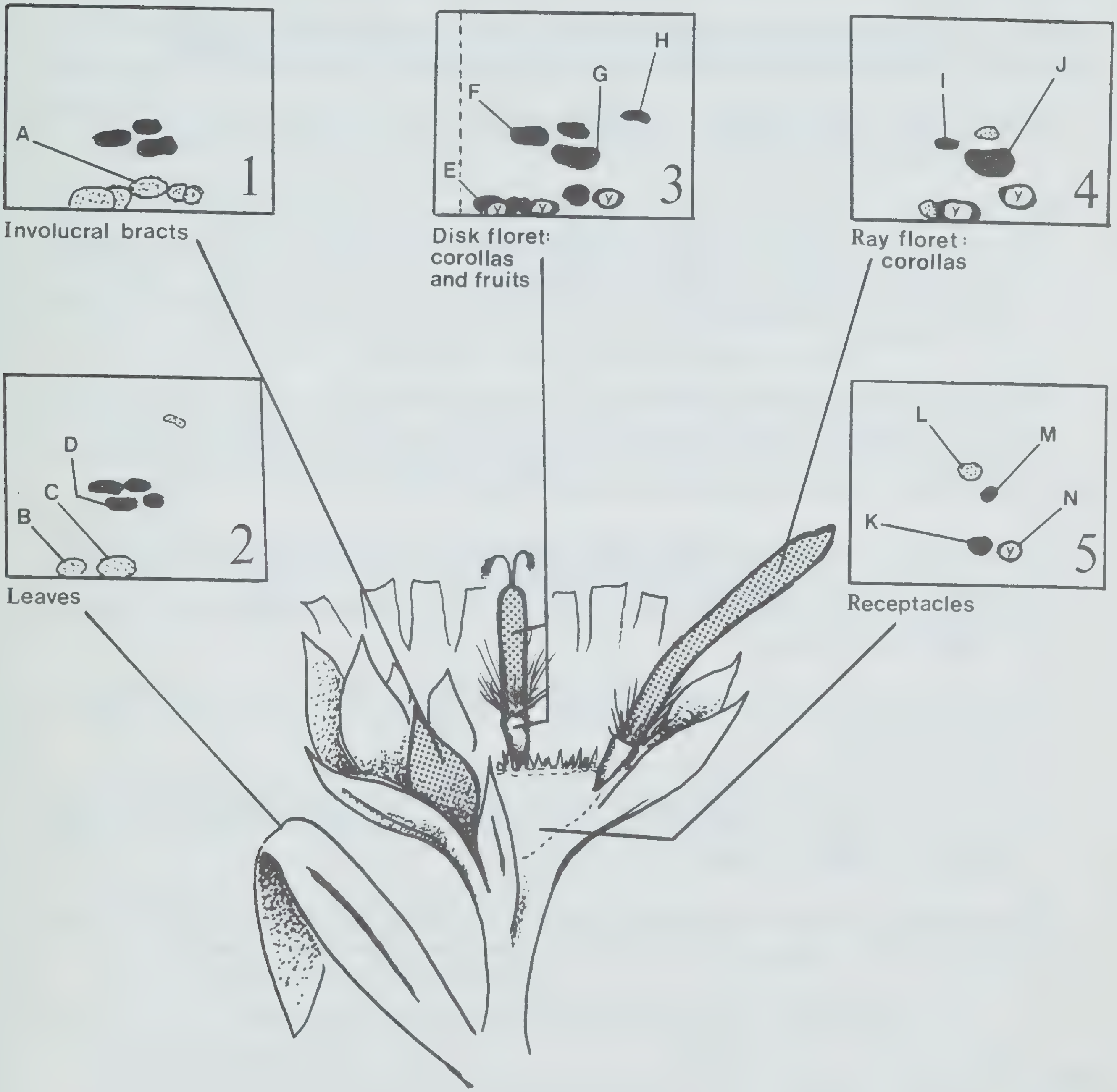


Figure 3(2).2 depicts two-dimensional chromatograms. These were prepared using chemicals extracted by 85% methanol from various parts of a flowering plant related to the sunflower. The extracts were then spotted on the chromatograms, and run with two solvents in two dimensions.

Most of the spots are purple when viewed under ultraviolet light but spots bearing a 'Y' are yellow. The more diffuse the spot in the drawing, the paler the spot.

Note that many spots on the chromatograms bear lettered labels. These will aid you in communicating information efficiently in answering the questions that follows. You need <u>not</u> use all of the letters in your answer, but you can use the same letter twice.

There are also numbers on each chromatogram. These should help you, in your answer, to make rapid references to the different groups of structures in the exercise (Part G).

A. Two labelled spots likely refer to the same chemical. Which two spots are they? Explain how you were able to decide.

B. The technique of two-dimensional chromatography uses two different solvents moving in directions perpendicular to one another (but not simultaneously). This should separate mixtures of chemicals having similar solubilities in one of the solvents. Which spot contains the chemical of greatest solubility difference in the two solvents used? Explain your reasoning.

C. The R_f value might be an indicator of a chemical's solubility in the solvent. Calculate the R_f value for the spot labelled 'G' (Chromatogram #3). Assume that the broken vertical line towards the left of the chromatogram represents the point where the solvent had reached when the chromatogram was stopped. Show all of your calculations.

D. What two chemicals were likely mixed together after chromatography using the first solvent (right to left movement of the solvent) but became separated during the chromatography using the second solvent (bottom to top movement of the solvent)? Explain briefly how you decided.

E. Which single spot contains a chemical having the same R_f in both solvents? Explain how you decided.

F. Of those labelled, which chemical is most widely distributed among the different floral structures studied and which is most restricted in its distribution? Tell where each of the two chemicals are found.

G. Briefly discuss the possible evolution of the various floral structures from one primitive structure. Use evidence from the chromatograms to support your ideas.

Response/Marking Scheme

A. G and J 1

Both have a similar appearance, and, more important, 1

both have reached a similar position on the chromatogram 1

under the influence of two entirely different solvents 1

Give credit for showing knowledge that standard papers and solvent formulations mean that there are standard positions on chromatograms for each chemical 1

Give credit for supporting answer with quantitative data from scales viz 16 units above X-axis and 25 units left of Y-axis. 1

B. E 1

because it has remained at the origin with the vertical solvent and 1

moved furthest away from the origin with the horizontal solvent. 1

Give credit for quantitative support viz 59 units leftward migration 1

C. $R_f = 0.45$ 1

derived by measuring solvent front (55 units) and spot front (25 units) 1

and dividing. (It is a ratio $25/55 = 0.45$) 1

D. D and C 1

Such chemicals would have the same horizontal position but 1

different vertical positions. 1

E. G or J 1

since they move the same distance in each dimension. 1

They must be on a line drawn 45° through the origin. 1

Give credit for pointing out that it must be assumed that the distance travelled by the solvent front was the same in each dimension. 1

F. G or J (M may be acceptable within the accuracy of these drawings.) 1

Found in three groups... #1, #3, and #4 1

and K or L 1

which are found only in the receptacles. 1

G. The intuitive feeling that some flower parts are more related to one other than other flower parts 1

is borne out by chemical evidence. There are more 1

chemicals on chromatograms #1, #2, and #4 1

Since chemicals isolated by a single technique (methanol) are likely similar, the number of spots could indicate how similar the parts are chemically and how close in evolutionary history. 1

Actually, five chemicals are shared by #3 and #4 1

and four were shared by these with #1. 1

This suggests that flower "petals" have diverged recently in evolution, and they 1

shared an ancestor with floral bracts before that. 1

Leaves, (#2), share about the same amount with receptacles as with "petals" 1

and receptacles share about as much with "petals" as with leaves. 1

Thus, probably neither leaf nor receptacle is a direct ancestor to the "petals". 1

However, the greater abundance of chemicals in the extracts of leaves than of receptacles 1

suggests a slightly closer relationship of "petals" to leaves than to receptacles. 1

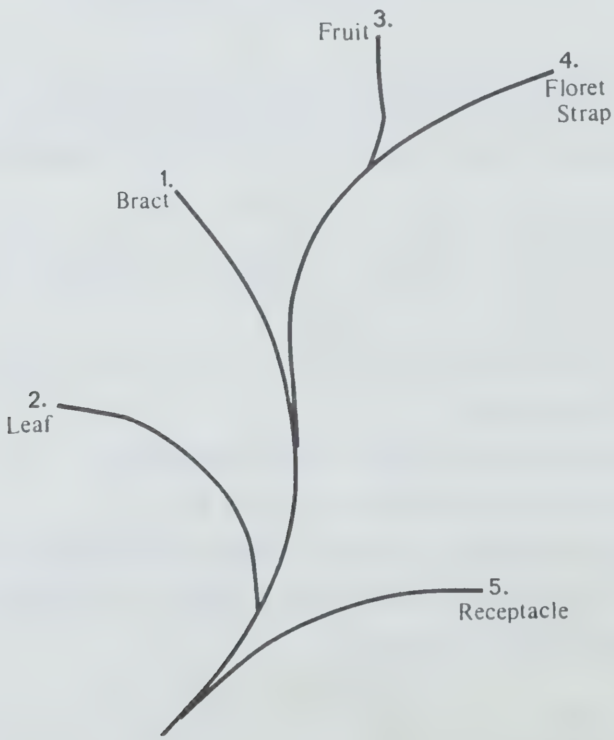
Give credit for a sketch of an evolutionary tree as indicated on the accompanying diagram. 1

Possible: 35

Maximum: 25

Teacher Notes

POSSIBLE EVOLUTION OF PARTS OF A PLANT



DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B032d-LP.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 32d
UNIT NUMBER: 03	INSTRUMENT TYPE: LP
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1-4, A.7, A.8, D.1-4, D.6, F.2
TOPIC: Chromatography	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Nature of Science	TIME ALLOCATION:

KEYWORDS: chromatography

Guideline Objective

The student will use paper chromatography to separate the pigments in a leaf extract.

Item Focus

The student should be able to design an experiment using chromatography to separate leaf pigments; and interpret the results of a similar experiment.

Item

You will be presented with a problem to be solved that will require you to design an experiment (Part A - 15 min). Then in Part B you will be given data obtained from an experiment and asked to interpret the data (25 min).

<u>PART A</u> (15 min)

Problem:

What pigments are present in the leaves of a given plant?

Design an experimental procedure to solve the problem using paper chromatography. Write your procedure and the list of materials you will require.

<u>PART B</u> (25 min)

The accompanying chromatogram (Figure 3(2).3) represents the results of separating a number of compounds from an extract of the lichen, *Cladonia*. Using the following table* of the Rf values of compounds found in this genus of lichens, analyze and interpret the chromatogram. (Assume that the chromatogram was run in the same conditions as were used to obtain the data given in the table.)

COMPOUND	R_f VALUE
atranorin	.95
baeomycic acid	.55
barbatic acid	.71
norstictic acid	.65
squamatic acid	.20
stictic	.33
strepsilin	.50
usnic acid	.95

* Data from Thompson, John W. *Lichen Genus Cladonia in North America.* Toronto: University of Toronto Press

Response/Marking Scheme

PART A

solvent (something that will effectively separate the pigments)	2
chromatogram - trim to run	2
running tank	1
saturating atmosphere of tank before running	1
extraction of pigments from the leaves	2
correct spotting and running of chromatogram	2
Maximum:	10

PART B

Calculation of Rf values: .95, .6, .3, .1, 0	3
Comparison to table	3
Interpretation:	
.95 could be either atranorin or usnic acid	1
.6 might be norstictic acid	1
.3 might be stictic acid	1
.1 an unidentified substance	1
0 an unidentified substance	1
Possible:	11
Maximum:	8

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Nutrient Availability
CURRICULAR EMPHASIS: Practical Application

INSTRUMENT CODE: B033b-ER.01R
GUIDELINE OBJECTIVE CODE: 33b 71Kb
INSTRUMENT TYPE: ER
KLOPFER: A.1, A.2, A.10, C.1, D.3
DIFFICULTY LEVEL: M
TIME ALLOCATION:

KEYWORDS: phosphates mineral deficiency soil pH

Guideline Objective

The student will be able to predict that any environmental factor that inhibits photosynthesis on a large scale will have disastrous consequences in the biosphere.

Item Focus

The student will explain the influence of the growth medium on the availability of raw materials, e.g., the effect of pH on nutrient availability (phosphates), the determination of habitat (sphagnum moss in acidic environments).

Item

A farmer was growing two crops of the same variety of corn in fields 100 m apart. In one field, all the leaves of the plants were of uniform, healthy colour, the plants were flowering and appeared well set to produce a fine yield of corn. In the other field, the plants were much smaller and they had not yet flowered. The leaves were a darker green than normal and the older leaves had bluish-purple spots on them.

Suspecting the trouble lay in the soil, the farmer had a soil analysis carried out by the Ministry of Agriculture on both fields. The analysis revealed that the soil from the "healthy" field had a pH of 6 and the soil containing the poor crop had a pH of 8.5. The poorer field also showed a deficiency of phosphorus. The agricultural representative used the evidence from the appearance of the plants and the soil analysis to make a correct diagnosis of the problem.

A. Give 3 reasons why a deficiency of phosphorus might affect the appearance of the unhealthy plants.

B. How did the pH affect the problem?

C. How could the farmer save his crop?

Response/Marking Scheme

A. Any three of the following: 3

- phosphorus is part of ATP and other nucleotides essential for nucleic acid synthesis, the synthesis of some proteins, some essential co-enzymes, and membrane phospholipids

- in addition, it is present in phosphorylated sugars in both respiration and photosynthesis reactions

- finally, phosphorus is present in inorganic and organic phosphates which act as buffers

- the bluish/purple spots are caused by an accumulation of anthocyanin pigments

- since phosphates are mobile nutrients, young parts of the plant have the ability to withdraw the nutrients from older parts, hence, deficiency symptoms showed up on the older leaves first.

B.

- the pH of the soil controlled the relative abundance of the two forms of phosphate available in the soils. 1
- the pH 6 of the soil with the healthy crop favoured the presence of the more readily absorbed $H_2PO_4^-$ ion. 1
- the pH 8.5 of the soil with the poor crop favoured the much less readily absorbed HPO_4^{2-} ion 1

C.

- the farmer should find a way of reducing the pH of the poor soil and add some superphosphate (i.e., fertilizer containing the available $H_2PO_4^-$ ion 2

Possible: 8

Maximum: 8

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B033b-ER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 33b.71Kb
UNIT NUMBER: 03	INSTRUMENT TYPE: ER
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
TOPIC: Nutrient Availability	DIFFICULTY LEVEL: L
CURRICULAR EMPHASIS: Solid Foundation	TIME ALLOCATION:

KEYWORDS: phosphates soil absorption pH

Guideline Objective

The student will be able to predict that any environmental factor that inhibits photosynthesis on a large scale will have disastrous consequences for the biosphere.

Item Focus

The student should be able to state the form in which nutrients can be absorbed by plants.

Item

A. In what form are phosphates most readily absorbed by plants?

B. Explain how the pH of the soil can affect the availability of these phosphates.

Response/Marking Scheme

A. Phosphates are most readily absorbed by plants in the form of monovalent ions ($H_2PO_4^-$) 1

B. The pH of the soil controls the relative abundance of the two forms of phosphate. 1

A soil pH of below 7 (optimum pH 5.5. to pH 6.5) favours the presence of the more readily absorbed $H_2PO_4^{2-}$ ion, most of which is present as insoluble calcium phosphate. 1

In some soils where the pH is low and there should be adequate $H_2PO_4^-$ ions available, there is a high concentration of aluminum ions (Al^{3+}) which cause the precipitation of the $H_2PO_4^-$ as aluminum phosphate. 2

Possible: 5

Maximum: 4

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B033b-ER.03
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: Part 1(3.3f) 33b
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	INSTRUMENT TYPE: ER
	KLOPFER: A.1, A.2, A.3, F.3, H.3, I.4
TOPIC: Science and society	DIFFICULTY LEVEL: H
CURRICULAR EMPHASIS: Science, Technology and Society	TIME ALLOCATION:

KEYWORDS: deforestation Amazon basin issues soil erosion

Guideline Objective

The student should use scientific information in the process of societal decision making.

Item Focus

The student will state two sides of an issue and show how people might make a decision based on the alternative views.

Item

Deforestation in the Amazon basin has caused a great deal of concern on the part of environmentalists. The potential reduction in photosynthesis, the erosion of thin topsoil, and,the potential for significant climatic changes has sparked world-wide debate.

A. Discuss two major reasons that you would give if you were asked to defend the practice.

B. Discuss two major reasons that you would give if you were not in favour of the practice.

C. How do people determine the relative importance to attach to the different points of view?

Response/Marking Scheme

A. Accept any two, such as
Makes economic sense; relatively inexpensive labour, trees are plentiful in the area, provides jobs and much needed economic infusion into the local economy. It is only a minor disruption because few humans live in the area. 2

B. Accept any two, such as
A significant reduction in the amount of photosynthesis may lead to a decrease in molecular oxygen production; biologists have no way of predicting the possible effects of this. The loss of topsoil leads to the creation of an area largely barren of vegetation. The disruption of the ecosystem results in the loss of a great number of organisms due to the destruction of their habitat. There is also disruption of drainage patterns of water runoff; biologists have no way of predicting the effect of this. 2

C. The relative importance of each point of view probably is determined by many factors, 1
many of which may not lie in the realm of science. 1
If the maintainence of the natural state of the Amazon basis is important to decision-makers, and economic reasons are secondary, then the deforestation will be stopped. 1
On the other hand, if economic factors are deemed as fundamentally more important, then the deforestation will continue. 1

Possible: 8

Maximum: 6

Teacher Notes

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B033cER.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: Part 1(3.1-11) 33c
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	INSTRUMENT TYPE: ER
	KLOPFER: I.2, I.4, I.5,
TOPIC: Science and Society	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Communication	TIME ALLOCATION:

KEYWORDS: food production food distribution decisions.

Guideline Objective

The student should develop a sensitivity about science and its influence on societal issues and values.

Item Focus

The students will choose a statement which best fits a particular attitude they hold about the scientific enterprise and support their choice.

Item

Some people think that scientists and engineers should be the ones to decide on world food production and food distribution (e.g. what crops to plant, where best to plant them, how to transport food efficiently, how to get food to those who need it, etc.). Others disagree. Who do you think should make the decisions?

Choose one of the following positions and produce an argument to justify your choice.

A. Scientists and engineers should decide because they have the training and facts which give them a better understanding of the issue.

B. Scientists and engineers should decide because they have the knowledge and can make better decisions than government bureaurocrats or private companies, both of whom have vested interests.

C. Scientists and engineers should decide because they have the training and the facts which give them a better understanding; but the public should be either informed or consulted.

D. The decision should be made equally; viewpoints of scientists and engineers, other specialists, and the informed public should all be considered in decisions which affect our society.

E. The government should decide because the issue is basically a political one; but scientists and engineers should give advice.

F. The public should decide because the public serves as a check on scientists and engineers. Scientists and engineers have idealistic views on the issue and thus pay little attention to consequences.

Response/Marking Scheme

Justification of the selection made:

Supporting argument
Coherence
Clarity — Maximum: 10

Teacher Notes

It may be that you would prefer to use this question for class discussion or debate, rather than evaluating opinions.

DRAFT

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B033c-ER.02
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: Part 1(3.3f) 33c
UNIT NUMBER: 03	
UNIT NAME: PLANT PHYSIOLOGY and PHOTOSYNTHESIS	INSTRUMENT TYPE: ER
	KLOPFER: H.2, I.4
TOPIC: Science and Society	DIFFICULTY LEVEL: M
CURRICULAR EMPHASIS: Science, Technology and Society	TIME ALLOCATION:

KEYWORDS: conservation issues

Guideline Objective

The student should use scientific information in the process of societal decision making.

Item Focus

The student will relate positive and negative aspects of lumbering in parkland.

Item

A continuing debate about the harvesting of trees for lumber in parkland causes emotional responses from those who agree and disagree with lumber companies.

A. From the point of view of people who live near the parkland, discuss two advantages of lumbering in the area.

B. From the point of view of people who live near the parkland, discuss two disadvantages of lumbering in the area.

C. How do decision-makers determine the relative importance to attach to each of the beneficial and harmful aspects?

Response/Marking Scheme

A. Possibility of jobs for people in the area. Increase in economic benefits to area in that workers will spend money in the local area. Possibility of new people moving into the area leading to an envigorated region. 2

B. Change in natural environment (cutting down of trees) may result in loss of habitat for birds and mammals. Potential loss of sense of commmunity. Increased traffic, noise, and disruption associated with increased numbers of people who do not necessarily have a committment to the community. 2

C. Decision-makers are involved in a political process. 1

In some cases, the deeply held beliefs are the deciding factors 1

(ideal of community is strong, or the idea of economic advancement for members of community is strong). 1

There do not seem to be generalizations that will hold in all cases. 1

Possible: 8

Maximum: 6

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology	INSTRUMENT CODE: B037b-MC.01
LEVEL: OAC	GUIDELINE OBJECTIVE CODE: 37b
UNIT NUMBER: 03	INSTRUMENT TYPE: MC
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS	KLOPFER: A.1, A.2, A.3
	DIFFICULTY LEVEL: L
TOPIC: Chlorophyll	TIME ALLOCATION:
CURRICULAR EMPHASIS: Solid Foundations	

KEYWORDS: porphyrin

Guideline Objective

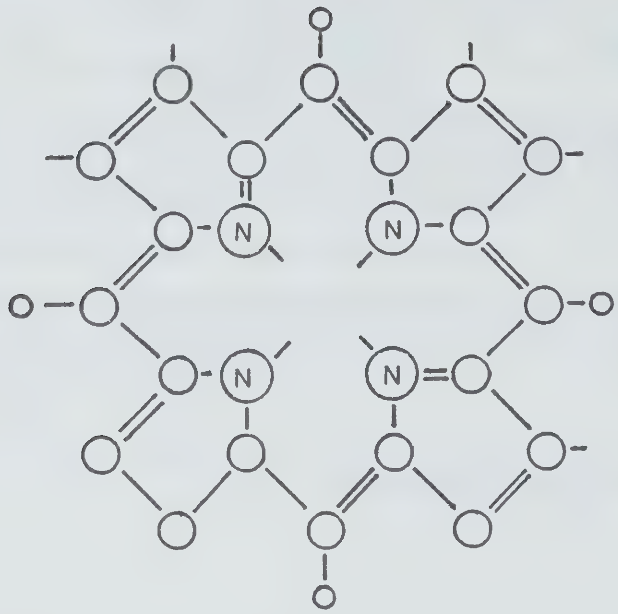
Some students might compare the function in a cell and the structural formulas of haemoglobin, cytochromes, and chlorophyll.

Item Focus

The student should be able to recognize a porphyrin.

Item

Refer to Figure 3(7).1.



Of which substance does Figure 3(7).1 represent a significant portion?

☐ A. nucleic acid

☐ B. chlorophyll

☐ C. enzyme

☐ D. fat

☐ E. starch

Response/Marking Scheme

Correct response: B

Teacher Notes

DISCIPLINE/SUBJECT: Science/Biology
LEVEL: OAC
UNIT NUMBER: 03
UNIT NAME: PLANT PHYSIOLOGY AND PHOTOSYNTHESIS
TOPIC: Biologically Important Molecules
CURRICULAR EMPHASIS: Solid Foundations

INSTRUMENT CODE: B037b-MC.02
GUIDELINE OBJECTIVE CODE: 37b
INSTRUMENT TYPE: MC
KLOPFER: A.1, A.2, A.3
DIFFICULTY LEVEL: L
TIME ALLOCATION:

KEYWORDS: porphyrin chlorophyll haemoglobin bile pigment cytochrome

Guideline Objective

Some students might compare the function in a cell and the structural formulas of haemoglobin, cytochromes, and chlorophyll.

Item Focus

The student should be able to identify the structural similarities among molecules having diverse functions.

Item

Many biologically important molecules contain a porphyrin ring in which a heme group functions as a carrier of oxygen or electrons. Which of the following would NOT contain a porphyrin ring?

☐ A. chlorophyll

☐ B. nucleic acid

☐ C. haemoglobin

☐ D. bile pigment

☐ E. cytochrome

Response/Marking Scheme

Correct answer: B

Teacher Notes